



CHART PROGRAM

MAPPING SYSTEM ARCHITECTURE

Version 3.0

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Document Revisions

Revision	Description	Pages Affected	Date
0	Initial Release	All	07/30/2014
1	Updates for R17	All	06/17/2016
2	Updates for R 17.2, R17.3	Updated cover Updated document references (pp. 3-4) updated diagrams (pp., 18-21, 29, 32-35, 42, 58, 122) Misc edits (pp. 23, 30, 44, 58, 64) Updated R17 patches in Release history (pg. 120)	06/15/2017
3	Updates for R18	All	08/15/2017

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1 INTRODUCTION

1.1 Purpose

This document presents the architecture of the Coordinated Highways Action Response Team (CHART) Mapping System. The architecture of the CHART Mapping system is presented as a number of different “views”, with each view representing a different perspective of the system.

1.2 Views Descriptions

Each view is described in Table 1-1. In addition, there are various appendices, described in Table 1-2.

Table 1-1. CHART Mapping Architecture Document Views

View Name	Description	Typical Stakeholders	Section
Feature List View	Provides a brief high-level overview of CHART Mapping and describes the features available in the system	Representatives from other agencies interested in CHART Mapping’s capabilities, as well as operators, support personnel, developers, and managers	2
Functional View	Describes basic CHART Mapping functionality and some key operational concepts that drove how the functionality has been implemented	Developers, managers and officials from other organizations, looking to interface with or build a system like the CHART Mapping	3
System View	Shows system components and how they connect to each other	System administrators, software developers and architects and others interested in the system-level architecture	4
Interface View	Describes the CHART Mapping external interfaces	Representatives from other agencies interested in CHART Mapping’s capabilities, specifically software and system architects who may be looking to interface with CHART Mapping	5
Data View	Describes how data moves into, out of, and around the CHART Mapping system	CHART Mapping database administrators (DBAs), management, developers, and stakeholders of connected systems	6
Deployment View	Describes the various CHART Mapping deployment configurations	Operations & Maintenance personnel, network engineers	7

View Name	Description	Typical Stakeholders	Section
Subsystem View	Describes CHART Mapping software/ hardware subsystems and Commercial Off-The-Shelf (COTS) products	Developers, configuration managers, and management	8
Standards View	Describes CHART Mapping support for mapping interface standards.	MDSHA management, developers, and those looking to interface with CHART Mapping for the purpose of consuming/display CHART Mapping data.	9
Business Architecture View	Describes CHART Mapping from a business process perspective	Business Area Architecture (BAA) process participants, those interested in CHART's business plan and its mapping to CHART capabilities	10
System Maintenance View	Describes Operations and Maintenance aspects of the CHART Mapping system	System administrators, software and system architects, others interested in CHART Mapping maintenance tasks	11

Table 1-2. CHART Mapping Architecture Document Appendices

Appendix	Description
A	Design studies performed during the development of the CHART Mapping
B	Database entity-relationship (ER) diagrams describing the design of the CHART Mapping database
C	Release history of CHART Mapping

1.3 Applicable Documents

Relevant documents associated with the system architecture are listed in the Table 1-3 below.

Table 1-3. Document References

Requirements and Vision
CHART Intranet Mapping Updated Software Requirements, February 2, 2003
CHART Internet Mapping Updated Software Requirements, February 17, 2003
CHART Intranet Mapping Updated Software Requirements Revision 1, September 30, 2003
CHART Intranet Mapping Updated Software Requirements Revision 2, June 9, 2004
CHART Intranet Mapping Updated Software Requirements Revision 3, September 16, 2008, WO5-RS-003R3

CHART Internet Mapping Updated Software Requirements Revision 1, September 16, 2008, WO5-RS-002R1
CHART Internet Mapping Updated Software Requirements Revision 2, February 27, 2009, WO5-RS-002R2
CHART Intranet Mapping Updated Software Requirements Revision 4, February 27, 2009, WO5-RS-003R4
CHART Intranet Mapping Public Data API System Requirements, March 31, 2010, WO5-RS-005
CHART Intranet Mapping Non Public Data API System Requirements, November 1, 2010, WO5-RS-006
CHART Release 5 Software Requirements, March 12, 2010, WO18-RS-001 (<i>includes Mapping R4 requirements</i>)
CHART Release 6 Mapping Release 5 Software Requirements, August 24, 2010, WO19-RS-001
CHART Release 7 Mapping Release 6 Software Requirements, February 8, 2011, WO21-RS-001
<i>No Official Requirements document for Mapping R7 - AVL</i>
CHART Release 9 Software Requirements Revision 1, December 22, 2011, WO24-RS-001R1 (<i>includes Mapping R8 requirements</i>)
CHART Release 10 Software Requirements Revision 2, July 17, 2012, WO28-RS-001 (<i>includes Mapping R9 requirements</i>)
CHART Release 11/Mapping R10 Software Requirements, October 24, 2012, WO31-RS-001
<i>No requirements update for Mapping R11 – Technology Upgrade</i>
CHART Release 12 Software Requirements Revision 1, October 8, 2013, WO35-RS-001R1 (<i>includes Mapping R12 requirements</i>)
CHART ATMS/Mapping R13 [sic] Software Requirements Revision 1, June 2, 2014, WO38-RS-001R1 (<i>includes Mapping R14 requirements</i>)
WO 39 CHART Mapping R14/CHARTWeb 2.3 Software Requirements, March 7, 2014, WO39-RS-001
WO42 Lane Closure Permit Application Phase 3/Mapping R15 Software Requirements Validation Revision 1, December 2, 2014, WO42-RS-001R1
<i>No requirements update for Mapping R16 – SHA Data Upgrade</i>
WO53 CHART ATMS R16 Software Requirements Rev 1, May 18, 2016, WO53-RS-001R1 (<i>includes Mapping R17 requirements</i>)
CHART WEB R3.3 MAPPING R17.3 AVL-GPS R2.3 ATMS R17.1 SOFTWARE REQUIREMENTS Version 2.0, February 13, 2017, WO12-CHART-RD-001-V2.0
CHART Business Area Architecture Revision 13, January 28, 2014, W01-BA-001R13

2016 Business Area Architecture Revision 17, March 15, 2017, CHART-OPS-014-v17
WO13 CHART Mapping R18 Software Requirements, February 25, 2017, WO13-MAP-RD-001
Design
CHART Mapping High Level Design, November 3, 2008, WO05-DS-001
CHART Intranet Mapping Detailed Design Revision , December 2, 2008, WO05-DS-003R1
CHART Internet Mapping Detailed Design Revision , December 2, 2008, WO05-DS-002
CHART Intranet Mapping Detailed Design, January 28, 2010, WO18-DS-002 (<i>Mapping R4</i>)
CHART Release 6 Mapping Release 5 Detailed Design, September 21, 2010, WO19-DS-001
CHART Mapping Detailed Design, February 8, 2011, WO21-DS-002
CHART Mapping R6 High Level Design, February 9, 2011, WO21-DS-001
CHART Mapping AVL Design Document, March 8, 2012 (<i>Mapping R7</i>)
CHART Mapping WO24 Detailed Design, August 5, 2011. WO24-DS-002 (<i>Mapping R8</i>)
CHART Mapping WO24 High Level Design, August 5, 2011. WO24-DS-002 [sic] (<i>Mapping R8</i>)
CHART R10 Detailed Design Revision 3, August 14, 2012, WO28-DS-001 (<i>includes Mapping R9 design elements</i>)
CHART Release 11 Detailed Design, November 26, 2012, WO28-DS-001 (<i>includes Mapping R10 design elements</i>).
CHART Mapping Release 11 Detailed Design Technology Refresh, January 31, 2013, WO32-DS-001
CHART Release 12 Detailed Design, September 20, 2013, WO35-DS-001 (<i>includes Mapping R12 design elements</i>).
CHART Release 13 Detailed Design Rev 1, February 27, 2014, WO38-DS-001 (refers to Mapping R14 design elements).
Mapping Release 14/CHARTWeb Release 2.3 Detailed Design, March 14, 2014, WO39-DS-001
WO 42 LCP Phase 3, Mapping R15 and ATMS 13.2 Detailed Design, December 22, 2014, WO42-DS-001
CHART ATMS Release 16 Detailed Design, April 21, 2016, WO53-DS-001 (<i>includes Mapping R17 design</i>)
CHART WEB R3.3 MAPPING R17.3 AVL-GPS R2.3 ATMS R17.1 SYSTEM DESIGN DOCUMENT, February 20, 2017, WO12-CHART-RD-002-V1.0
CHART Mapping Release 18 Detailed Design, July 10, 2017, WO-13-MAP-RD-002
Studies

CHART System Database Strategic Plan, April 21 2011
Configuration Management
CHART Change Management Plan, December 22, 2016, CHART-OPS-003v1.0

2 FEATURE LIST VIEW

2.1 View Description and Typical Stakeholders

This view provides a brief high-level overview of the CHART Mapping system and describes the features available in the system. This section is suitable for those who would like to have an easy-to-digest list of features CHART Mapping provides, such as representatives from other agencies interested in CHART Mapping's capabilities, as well as operators, support personnel, developers, and managers just coming in who are new to CHART Mapping, or who would like a quick refresher.

2.2 CHART Mapping Overview

The CHART Mapping system consists of a database server and an application server hosting the CHART Intranet Map, and several Mapping services which provide information to other CHART applications such as the Advanced Traffic Management System (ATMS), the Emergency Operations Reporting System (EORS) V2, and Lane Closure Permits (LCP). There is also a server (known as the iMap server) that serves mapping information to entities that are external to CHART, such as MEMA's Osprey system.

The basic components of the CHART Mapping applications include the CHART Intranet Map, iMap REST services, and a suite of REST services that provide information to other applications.

The CHART Mapping applications run on Windows Server 2012, and utilize MS SQL Server 2014, .NET Framework from version Version 4.6.2, ESRI Javascript API version 3.9, and HTML 5.

The routine operations of the Intranet Mapping application include:

- Map Navigation – Provides the capability to identify, measure, and generally navigate the CHART Intranet Map.
- Locator – Provides the capability to locate routes, exits, mile markers, mileposts, FITMSs, Signals, etc.
- Map Point and Line Events - ATMS Traffic Events, LCP Closures, EORS Route Restrictions
- View static devices – Provides capability to view location and status for CCTV, RWIS, DMS, HAR, SHAZAM, TSS, Signals, Salt domes
- View dynamic data – Provides capability to view CCTV video, AVL, TSS data, INRIX speed data
- Internal Mapping services – Provide this service tier for other CHART applications: Areas of Responsibility, Decision support, Lane configurations, Exit Milepost information, Map tiles, Exit and milepost tiles
- External Mapping services – Provides an interface for external applications to get Mapping data. There are three basic interfaces: AVL, Public, Non-Public. There is also a KMZ service. These interfaces contain a subset of the data available internally, although the data is much the same.

2.3 Feature List

The complete list of all features supported by the CHART Mapping is shown below:

- Map Navigation
 - Identify
 - Measure
 - Full Extent
 - Zoom to Previous Extent
 - Zoom to Next Extent
 - Pan
 - Clear Graphic(s)
 - Zoom In/Out
 - Refresh
- Map Views
 - By region, county, district or op center
 - Street, satellite, or hybrid
- Locator
 - Locate Route
 - Locate Landmark
 - Locate FITM
 - Locate Signal
 - Locate Coordinate
 - Locate AVL
- Map Closures/restriction
 - Map LCP Pending, Planned, Active closures
 - Map EORS route restrictions
- ATMS Traffic Event Viewing (list/map)
 - Incidents
 - Action
 - Planned Closures, Congestion, Special, Disabled Vehicle
- Static location device viewing
 - CCTV camera
 - RWIS
 - DMS
 - HAR
 - SHAZAM
 - Signal
 - TSS
 - Salt Domes

- Static location ‘Other’ layer viewing
 - FITM
 - Landmark
 - 911
 - MSP
 - Bridges
 - SHA office, lab, garage, shop
 - Toll booth
 - Light Rail, Subway, MARC station location
- Semi-static data viewing
 - County Summary
 - Area Wide Road Conditions
 - Snow Emergencies
 - Winter Storm Management Segment
- Dynamic data viewing
 - CCTV Video
 - AVL
 - TSS speed updates
 - RWIS
 - Salt Dome balance
 - INRIX speed data
- Internal Mapping services
 - Areas of Responsibility
 - Decision Support
 - Lane Configuration
 - Exit and milepost information
 - FITM information
 - Background Map tiles
 - Exit and Milepost tiles
- External Public/Non-public Data API Service
 - CHART ATMS Device
 - CHART ATMS Events
 - Lane Closure Permit data
 - EORS Route restrictions
 - RWIS
 - Snow Emergency Plans
 - Area Wide Road Conditions
 - Salt Domes

- POI
- Winter Storm Management Segments
- AVL

3 FUNCTIONAL VIEW

3.1 View Description and Typical Stakeholders

This view into the CHART Mapping describes basic CHART Mapping functionality and some key operational concepts that drove how the system was constructed. This is not a User's Guide or tutorial. Although there are some design concepts presented, it does not get to the level of a formal design document. See the CHART Mapping User's Guide for additional information. This view is useful for anyone interested in how the CHART Mapping works at a high level, including developers, SHA management, MDOT management, and officials from other organizations, looking to interface with or build a system like the CHART Mapping.

3.2 CHART Mapping Web-based Graphical User Interface

The CHART Mapping GUI is web-based application that is used to view CHART related data on a map. Users connect to the CHART Mapping GUI via any web browser (currently Microsoft Internet Explorer 11 is the officially supported browser, although other browsers may work as well).

The GUI consists of a tabbed section for the map legend/layer list, Event list, and Locator. There is a toolbar for map navigation and a tabbed menu for specialized map "default views" that are catered to different user-classes based on their typical desired functionality. The main map view contains data layers as indicated on the layer list against a backdrop of tiled base layer imagery (roads, satellite, traffic, hybrid). An additional toolbar provides support for zooming to pre-defined locations and links to external resources like Help.

3.3 Map Navigation

- Map Navigation
 - Identify
 - Measure
 - Full Extent
 - Zoom to Previous Extent
 - Zoom to Next Extent
 - Pan
 - Clear Graphic(s)
 - Zoom In/Out
 - Refresh

The Mapping application GUI main map page has a number of controls available.

3.3.1 Pan and Zoom

The user may pan using the controls on the Mapping window or by clicking and dragging. In addition the scalebar on the left side of the map area can be used to zoom in or out to pre-set levels.

3.3.2 Identify

Users can retrieve attribute information about roads based on a user-defined location on the map

3.3.3 Measure

Users can measure straight line distances by clicking locations within the map

3.3.4 Full Extent

Users can return to the default extent of the map in its initial load state

3.3.5 Clear Graphics

Removes user drawn graphics from the map

3.3.6 Refresh

Users can refresh data layers that are being displayed on the map.

3.4 Locator

The Locator tab provides a way for users to quickly zoom the map to pre-defined locations based on feature of interest.

- Locator
 - Locate Route – Users can find locations on the map based on Route names, Exits, County Milepoints, State Mileposts, Mile markers and road intersections
 - Locate Landmark – Users can easily find and zoom to locations of interest within the map by selecting from the Landmark dropdown menus
 - Locate FITM – Easily zoom to and display FITM plans based on Route names/numbers
 - Locate Signal – Search for signals based on Keyword and then zoom the map to the resulting signal location
 - Locate Coordinates – Type location coordinates in State Plane or Lat/Lon spatial reference and zoom to that location
 - Locate AVL – Search for vehicles based on keyword and category (such as Call Sign, Vehicle Number, Vehicle Name) and then zoom the map to the resulting vehicle location.

3.5 Map events/closures/restriction

The CHART Mapping GUI can be used to denote and store the location of closure and restriction events when used in conjunction with the ATMS and LCP subsystems. Users of those systems are directed to the Mapping GUI with information to zoom them to the general location of their

closure based on attribute information. Users can then refine their closure location using the mapping navigation tools.

- Map events/closures/restriction
 - Map LCP closures – LCP closure locations can be recorded within the map at the starting point of closure by interacting with the map and the Closure tab (available when entering the system from another subsystem such as ATMS or LCP)
 - Map EORS route restrictions – EORS route restriction locations can be recorded within the map as either point or point and line locations by interacting with the map and the Closure tab (available when entering the system from another subsystem such as ATMS or LCP)
- Saving point and line locations – CHART Mapping GUI allows users to interact with the map to define the location of route restrictions/closures. Users click on the map to define point locations and those locations are then “snapped” to the closest known point on the specified road. When users define end point locations for route restrictions/closure the CHART Mapping GUI will use the start and end point locations in conjunction with the roads centerlines (from the CHARTBG database) to build a line feature that corresponds to the given start and end locations. These point and line features are then persisted to an ArcSDE database and retained for display back to users. Please note, only point locations for closures are shown on the Intranet Map.

3.6 Static location device viewing

CHART Mapping provides users with a viewing platform for static device locations and attribute information. Each of the device types has a dedicated layer within the legend that can be enabled/disabled. Each of the individual device point locations has an icon that can be hovered upon to view complete attribute information about the specific device. All devices are based upon mapping layers that are continuously updated in the background to provide users with the most up to date attribute information for each feature on a timely basis. Certain layers also provide support for the click event which enables a popout window to display further information about the feature, including video streams. All layers in this category will periodically refresh themselves without user interaction to provide the latest information to users.

- Static location device viewing
 - CCTV camera – static camera locations that support click functionality to bring up a popup window with streaming video
 - RWIS – Road weather sensors provide latest information about road surface conditions and are categorized/colorized based on specific weather categories
 - DMS - Dynamic message signs are represented by static point icons that support hover to display the current message on the sign. Point icons are categorized based on the current online/offline status of the sign
 - HAR – Highway Advisory Radio point locations include current attribution about the radio station
 - SHAZAM – SHAZAMs are painted signs with beacons that flash to alert motorists to tune their radios to a station playing HAR messages. These are

represented by static point icons that support hover to display on/off status. Point icons are categorized based on the current online/offline status of the SHAZAM

- Signal – the signal layer provides a very densely populated view of all signals in the system. This layer is only available at close zoom ranges due to the large number of features
- TSS – Traffic Speed Sensors provide up to date information about the speed on each road segment. The features are symbolized based on speed ranges and the arrow icons are rotated to match the underlying road line feature
- Traffic Event – Traffic event icons represent the most up to date traffic event information exported from the ATMS system.
- Salt Domes – Salt dome features provide a visual representation of the location and quantity of salt available at each dome location. Attribution includes the percentage full at each dome and the symbology categorizes each feature by high or low balances of salt

3.7 Semi-static data viewing

Semi-static dataset are those that are only present when certain conditions are satisfied. These layers are not always visible if they do not contain any qualifying features.

- Semi-static data viewing
 - Road conditions – Areawide Road Condition (IPS) point layers that indicate driving lane weather conditions
 - Snow Emergencies - a polygon layer that has transparent crosshatching when a county is designated as a current snow emergency area
 - County Summary – a point layer that indicates the overall roadway/event status for the county
 - Winter Storm Management Segment (WSMS) – a line layer that depicts road surface conditions on a particular segment of roadway

3.8 Dynamic data viewing

Dynamic datasets are those which provide dynamic, updating data from statically located devices.

- Dynamic data viewing
 - CCTV Video - Live video streaming from roadway-mounted devices
 - AVL – Automated Vehicle Location points are GPS-enabled vehicles which can be tracked within the Mapping system. These point location may also be associated with camera feeds in which case they will be clickable and open a popup video viewing window
 - TSS speed updates – Roadway sensors provide up-to-date information about current speed rates on TSS-enabled roads
 - INRIX speed data – INRIX speed data is provided by a third party vendor and is displayed as symbolized line features on the map. Colors indicate speed ranges as provided by INRIX. This dataset updates periodically.

3.9 Internal Mapping services

These are spatially-enabled services provided to internal clients as part of a web-based service oriented architecture tier. Requests/responses to these services are provided via xml over HTTP.

- Areas of Responsibility - Allows management of AOR's [create, update, delete] and specific queries to retrieve AOR's based on application, location modified date
- Decision Support – This service uses ESRI's Network Analyst to provide route solutions for a given list of devices and a reference traffic event. Determines number of turns, u turns, etc and provides detailed directions. Also provides closest exit information used for suggesting messages for DMS/HAR. ATMS uses this service to provide the best devices to suggest in response to a traffic event. The Network Analyst dataset is an ESRI construct based upon the CHARTBG road centerlines. Centerline geometry is used in conjunction with elevation, impedance (speed limits/road type), one-way designations and travel restrictions to build a routable roads network to assist in the travel decision solutions used by ATMS.
- Lane Configuration - Defines an interface to obtain information about Lane Configurations from the GIS System. External systems can issue data requests (via HTTP) and receive requested data in the form of an XML document. The GIS Lane Configuration Web Service provides a REST web service interface which can be used to get or store lane configurations.
- Exit and milepost information - Defines an interface to query GIS information including State boundary geometry, county boundary geometry, milepost types, exit information, latitude/longitude for mileposts.
- FITM information - Defines an interface to query FITM plan information to be used in the CHART system. The FITM plan information includes: location of the FITM plan and file name that contains the plan.
- Background Map tiles – A tiled cache service that provides background imagery for various CHART websites. The tiles are pre-cached and contain information for road centerlines, water bodies, parks, etc.
- Exit and Milepost tiles – A tiled cache service that provides background imagery containing roadway exits, state milepost and mile markers.

3.10 External Public/Non-public Data API Service

The Public Data API defines an interface between CHART and a Service Requesting Client Application System. The interface provides a variety of CHART information to the Requesting Client via an HTTP/S interface when requested. The data is served via an ESRI Standard REST service output format. There are versions of the data that are fully accessible to the public as well as versions of the data that are available only to authorized users via login/password.

The following are the types of data that are available via these interfaces:

- CHART ATMS Device

- CHART ATMS Events
- Lane Closure Permit data
- EORS Route/Area restrictions
- RWIS
- Snow Emergency Plans (SEP)
- Speed Sensors (TSS)
- Dynamic Message Signs (DMS)
- Close Circuit Televisions (CCTV)
- Area-wide Road Condition Reports (IPS)
- Salt Domes
- POIs
- AVL

The following interfaces are available for consuming this data:

- CHART Public KMZ (Public)
- CHART Public Mobile (Public)
- CHART Public PC (Public)

- CHARTAVL_REST (Restricted)
- iMap_Non_Public (Restricted)
- iMap (Restricted)

In general, the Public interfaces contain high-level non-sensitive data while the restricted interfaces contain more detailed and potentially sensitive data.

Consumers of the restricted data include the Maryland Emergency Management Agency (MEMA) Osprey system and the University of Maryland. Not all consumers of the Public interfaces are known but they include a public-facing Osprey mapping application, and an MDTA video application.

These REST services are hosted in the DMZ at the MDOT Glen Burnie Data Center and provide data from internal (CHART/MDOT) CHARTWeb database.

More detail on the contents of these interfaces can be found in the *CHART Intranet Mapping Non Public Data API Interface* and *CHART Intranet Mapping Public Data API Interface* documents.

3.11CHART Mapping Data Sources

The data contained in the CHART system is a combination of external data sources and internally generated data. The roads centerlines are the basis for much of the system generated data. Centerline data is obtained from the State Highway Administration (SHA) on a periodic basis and integrated into the CHART system. Event based data, sensors, cameras, video cameras, closures, vehicles and other point-based data are then overlaid on these centerlines as data is

generated and streamed into the system by a variety of methods. External data sources like INRIX traffic data are polled periodically by client applications for updated status.

4 SYSTEM VIEW

4.1 View Description and Typical Stakeholders

The System View describes what the CHART Mapping hardware components are, how they are configured, what they support, and how they connect to each other. This view focuses on the internal structure of the system and its components (the view from within), whereas the Interface View focuses on external interfaces (the view from outside). This view will be of primary use to system administrators, software developers and architects and others interested in the system-level architecture.

4.2 System Overview

4.2.1 CHART Description

Figure 4-1 presents an overview of the CHART Program Architecture organized according to the Enterprise Architecture Framework as defined by the National Institute of Standards and Technology and how the CHART Mapping fits within it. This approach gives a holistic view of the enterprise and is organized into 5 layers:

- Enterprise Business Architecture Layer
- Enterprise Information Architecture Layer
- Enterprise Application Architecture Layer
- Enterprise Application Integration Architecture Layer
- Enterprise Infrastructure Architecture Layer

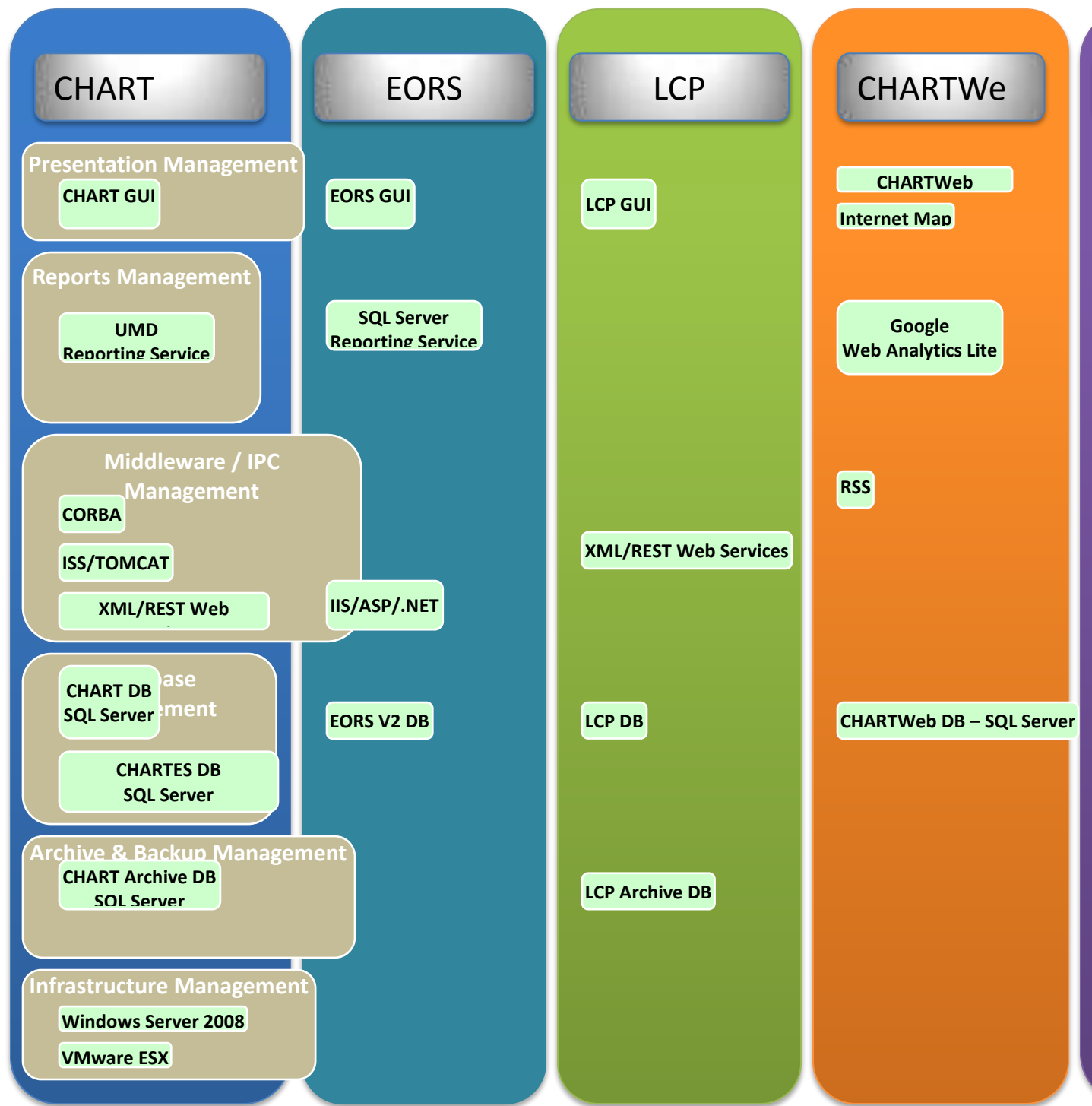
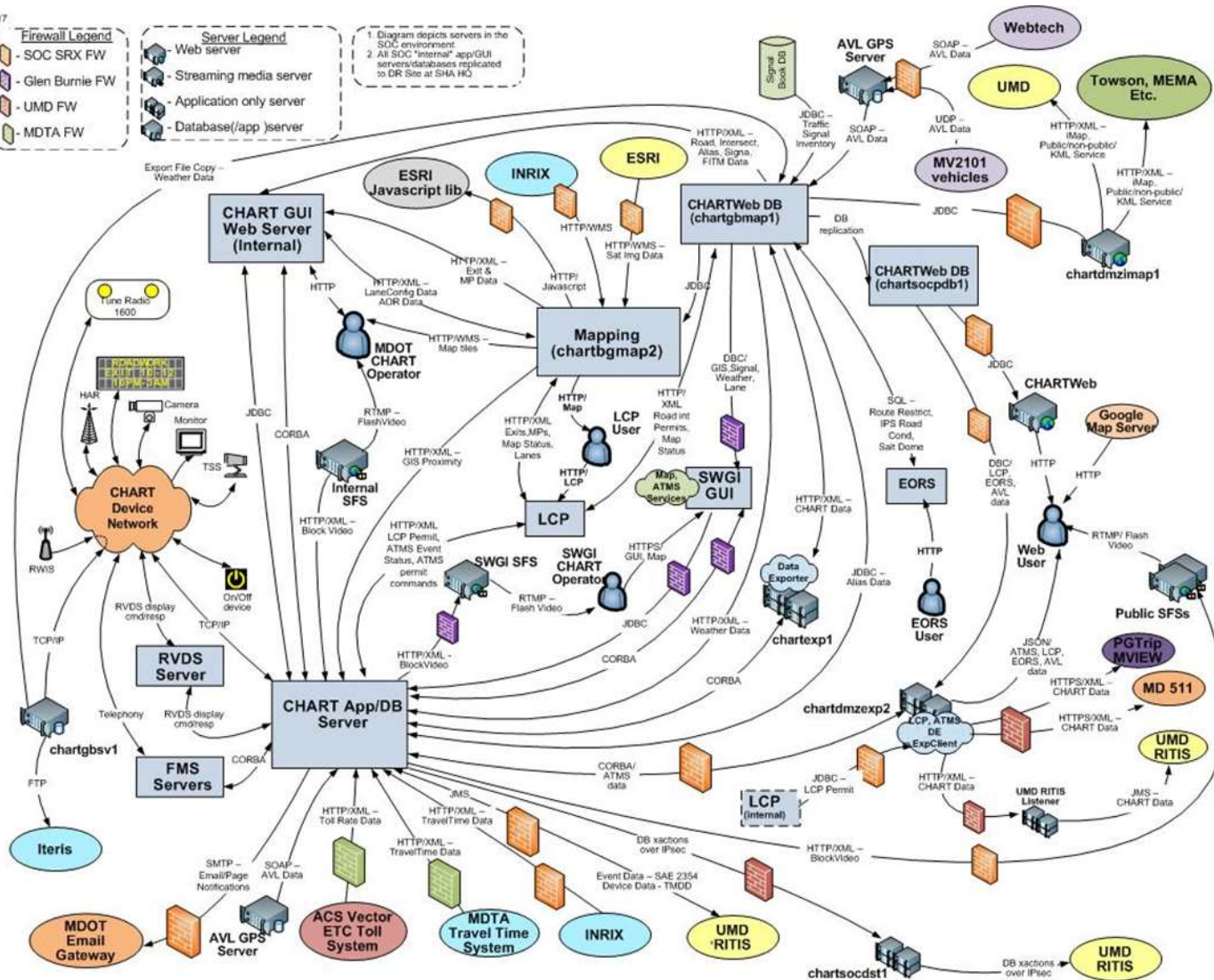


Figure 4-1. CHART Architectural Overview

The next two diagrams show various views of the CHART system architecture and how CHART Mapping fits within it. Figure 4-2 presents a high-level connection oriented architecture diagram showing how all of the internal and external systems connect to each other. Figure 4-3 presents a more detailed view of the components specific to the CHART Mapping System.



4.3 Software components

4.3.1 Software CIs

There are 6 software CIs comprising the CHART Mapping system.

Internal Map REST Services – This CI consists of those services providing direct support to the CHART operations staff. This includes the backend applications and the Map GUI.

Map Web Services – This CI consists of those services which provide mapping related and spatial related information in response to requests from other CHART applications.

External Map REST Services – This CI consists of those services which provide data to consumers external to CHART.

AVL Client – This CI consists of the application that consumes AVL data for use by Mapping.

COTS – This CI is a collection of all the COTS packages used by the CHART Mapping. These are collected into a CI for configuration control purposes.

Database Instance – This CI consists of the Mapping databases: CHARTWeb and CHARTBG. These databases are read by other CHART applications: ATMS web services, CHARTWeb

4.3.2 Communications

4.3.2.1 Database communications

External entities exchange data directly with CHART Mapping via the CHARTWeb database. These entities are internal to CHART and include ExportClient and CHARTWeb. Export Client transfers data from ATMS (devices, events) and LCP (roadway closures) into the CHARTWeb database.

In addition some internal CHART applications exchange data with CHART Mapping via database links. These applications include EORS V2. Lufft roadway weather data is imported by reading csv files and saving the contents to the database. The csv files are provided by the Lufft export job that runs periodically.

4.3.2.2 Web Services Description

External entities receive CHART Mapping data via an HTTPS/XML interface. The HTTPS/XML interface provides security features and data filtering capabilities. These entities are internal to CHART and include ATMS and LCP.

4.4 Database

The overall CHART Mapping database architecture is shown in Figure 4-4.

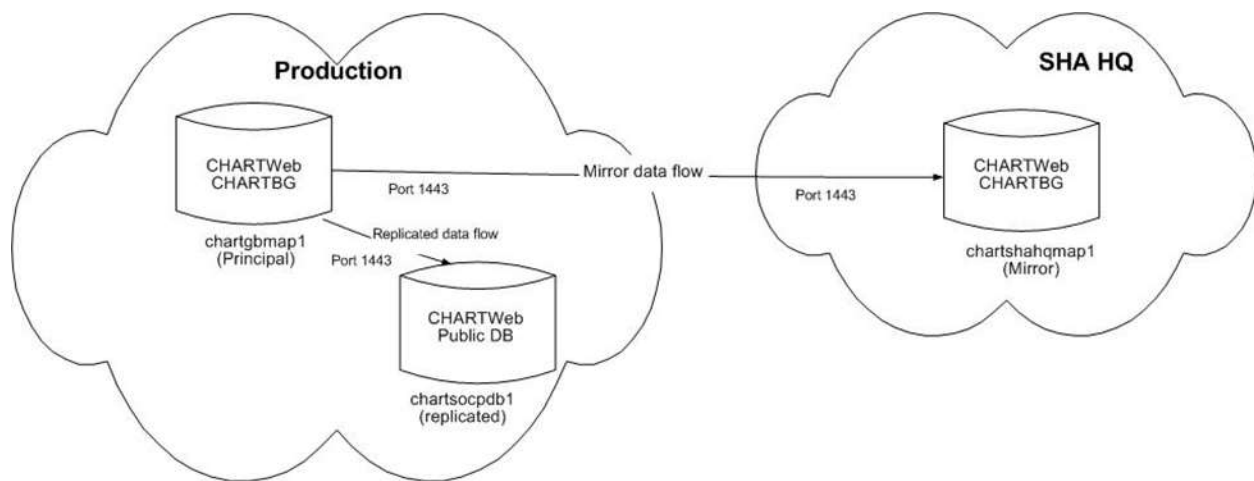


Figure 4-4. Mapping Database Architecture

Both databases are mirrored to SHA Headquarters. The mirror databases are used for disaster recovery scenarios. In addition the CHARTWeb database is replicated to a different server in the production environment. This “public” database is read by applications residing in the production DMZ, including CHARTWeb and the CHART Export Client, to minimize security risks with the CHARTWeb database utilized by internal CHART applications.

4.4.1 Archiving

Data in the Mapping databases (CHARTWeb and CHARTBG) is not directly archived. The CHARTBG data is static and is never archived. Although CHARTWeb data is dynamic, most of the data in that database is imported in some manner from other CHART applications and then supplemented with geospatial attributes. The applications that “own” the source data (i.e., ATMS, LCP) do archive that data.

4.4.2 Mirroring

The two CHART Mapping databases, CHARTWeb and CHARTBG, are mirrored from the Principal location at the MDOT Glen Burnie Data Center to the Mirror location at SHA Headquarters (HQ). This provides a duplicate copy of each database at SHA Headquarters, to be used by CHART Mapping and ATMS services running at the SHA Headquarters failover site. These services are not running routinely. Before they can run, the mirrored databases at SHA Headquarters must be set to be Principal.

4.4.3 Replication

The CHARTWeb and CHARTBG databases are replicated to a different server in the production environment. These “public” databases are read by applications residing in the production DMZ, including CHARTWeb and the CHART Export Client, to minimize security risks with the CHARTWeb and CHARTBG databases utilized by internal CHART applications.

4.5 Hardware components

This section presents the hardware CIs that make up the CHART Mapping. Each hardware CI is described and a list of major components is provided.

4.5.1 Hardware CIs

There are 3 hardware CIs.

CHART Mapping Application Server – Supports CHART Mapping applications.

CHART Mapping Database Server – Supports the CHARTWeb Database Instance and CHARTBG database instance.

CHART iMap Server – Supports export of CHART Mapping data to external entities.

4.5.2 CHART Mapping Application Server Description

The CHART Mapping application server system supports the CHART Mapping software CIs. This system consists of a server along with associated storage array and network connection devices. These systems are currently deployed in a virtual environment at the MDOT Glen Burnie Data Center (GB-DC), and on an identical backup at SHA Headquarters in Baltimore.

The CHART Mapping Application Server system configuration is:

Intel XEON X5650 2 processor 2.67 GHz

12 GB Total SDRAM

80 GB C drive; 240 GB D: drive

DVD Drive

Gigabit NIC card

4.5.3 CHART Mapping Database Server Description

The CHART Mapping Database Server supports the CHARTWeb and CHARTBG databases. The CHARTWeb database is used to store location enabled CHART data from the various CHART applications for display on the CHART Intranet map, and CHARTWeb. In addition that data is made available through the CHART Mapping iMap external REST services. There are two CHART Mapping Database Servers: a primary one at the GB-DC and an identical backup at SHA Headquarters in Baltimore.

The CHART Mapping Database Server system configuration is:

Intel XEON X5650 4 processor 2.67 GHz

16 GB Total SDRAM

80 GB C: drive, 280 GB E: drive, 40 TB F: drive

DVD Drive

Gigabit NIC card

4.5.4 CHART Mapping iMap Server Description

The CHART Mapping iMap Server supports the export of CHART Mapping operational data. There is one iMap server located in the DMZ at the GB-DC. There is no backup capability for these servers, so iMap services may not be available in certain CHART/Mapping failover scenarios.

The iMap Server system configuration is:

Intel® XEON X5650 2 processor 2.67 GHz

4 GB SDRAM

80 GB C: drive

Gigabit NIC card

5 INTERFACE VIEW

5.1 View Description and Typical Stakeholders

The Interface view describes connections to systems and users outside of CHART Mapping. CHART Mapping's has external connections to ingest data for use in CHART Mapping. It also has interfaces to provide data to external entities that may then re-package the information for presentation to their end-users. Finally CHART Mapping receives and responds to requests for geospatial related data. In some cases the consumers are actually other CHART systems such as ATMS and LCP. In other cases consumers are systems which are external to CHART

Typical stakeholders of this section are representatives from other agencies interested in CHART Mapping's capabilities, specifically software and system architects who may be looking to interface with CHART mapping.

5.2 External Interfaces

Figure 5-1 shows the external interfaces to CHART Mapping. In this context CHART Mapping includes both the Mapping application(s) and the CHARTWeb database. Often the CHARTWeb database is the intermediary between other CHART applications (e.g., LCP) and CHARTWeb. Thus that interface is depicted in the diagram even though CHART Mapping is not the "owner" of the data. These other CHART systems often interface with each other as well however as the focus of this diagram is CHART Mapping those interfaces are not included here.

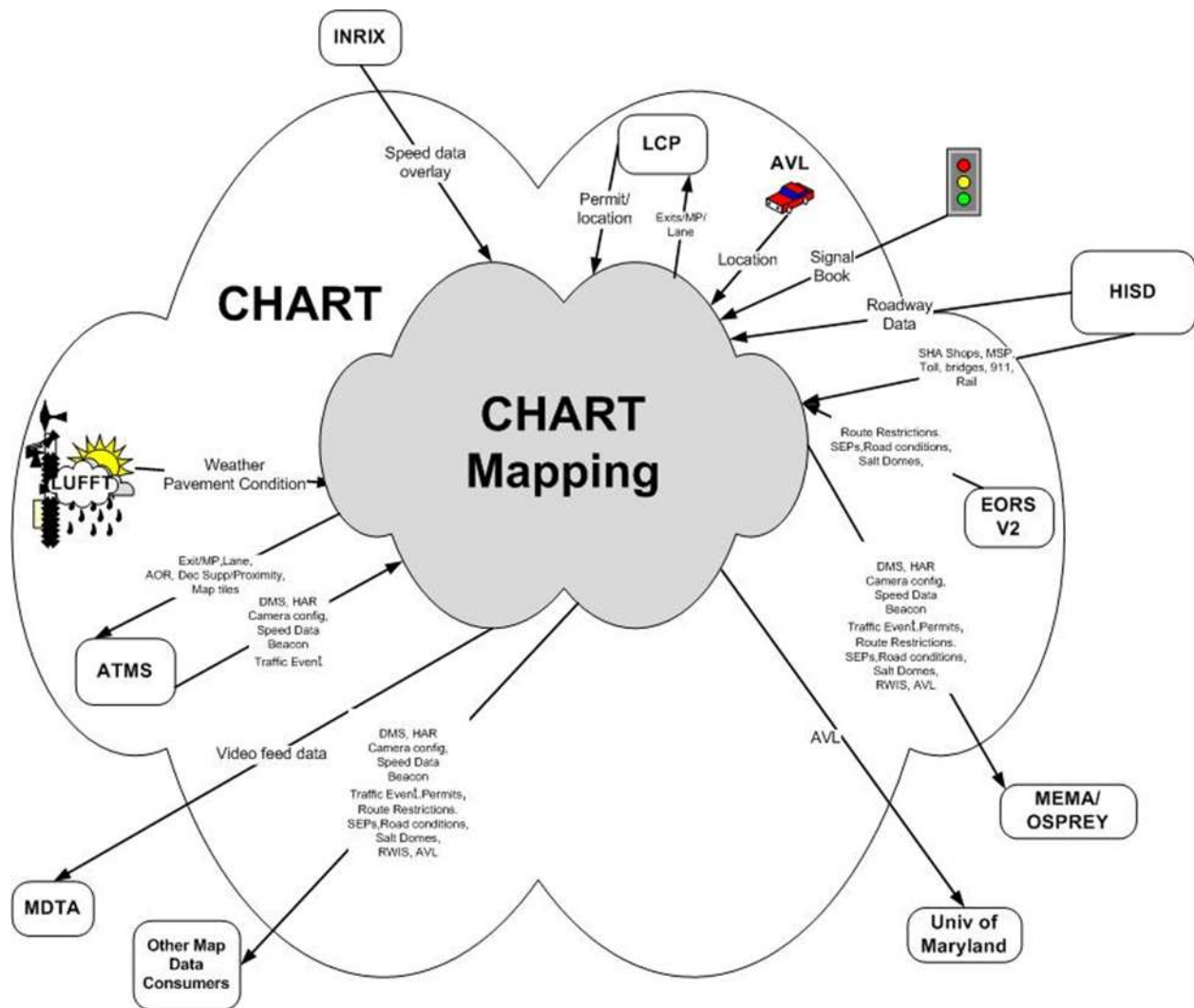


Figure 5-1. CHART Mapping External Interfaces

CHART Mappings's external interfaces consist of:

CHARTWeb – This public-facing site displays ATMS data (incident reports, lane closures, speed data, DMS messages, and camera configurations), LCP Data (lane closure permit data), EORS data (route restrictions, weather related road conditions, Snow emergency Plans), and Roadway Weather information System (RWIS) data obtained via the external export client.

Lane Closure Permits (LCP) – System providing permit information on planned and active road closures and road status. LCP queries Mapping services for exit/milepost data. LCP also queries Mapping services to get roadway lane configuration information.

LCP also provides data to CHART Mapping via the **CHART LCP Data Exporter/Export Client**. The CHART LCP Data Exporter provides data to client applications including the Export Client. The Export Client could be considered internal to the Mapping application. The Export Client writes data to the CHARTWeb database for consumption by CHART Mapping. This is the mechanism consuming LCP data and is not depicted explicitly in the diagram.

Emergency Operations Reporting System (EORS) V2 – System providing information on route restrictions, area wide road conditions, Salt Dome usage, Snow Emergency Plans, and winter storm management segments.

CHART Advanced Traffic Management System (ATMS) – ATMS queries Mapping services to get various geospatial related data. This includes exits/mileposts, lane configuration data, and device/event proximity information related to decision support. ATMS also queries mapping services to read/write polygons for Areas of Responsibility. The ATMS also provides data to CHART Mapping via **the CHART ATMS Data Exporter/Export Client**. The CHART ATMS Data Exporter provides data to client applications including the Export Client. The Export Client could be considered internal to the Mapping application. The Export Client writes data to the CHARTWeb database for consumption by CHART Mapping. This is the mechanism consuming ATMS data and is not depicted explicitly in the diagram.

Lufft – System to supply weather sensor data including pavement conditions to CHART applications. The CHART Mapping database imports Lufft data by reading csv files that provide current weather conditions. The weather conditions are displayed on the Intranet Map.

INRIX –Provides roadway speed data layers for display on the Intranet map.

Signal Book – CHART Mapping accesses the SHA Signal Book database containing locations of non-CHART, state-owned arterial devices including traffic signals, cameras, beacons (school, bridge, and warning), pre-emption signals (fire, bus, and rail), reversible lane signals, and weigh station devices.

AVL – Automatic Vehicle Location system provides real-time vehicle locations over a SOAP interface which CHART Mapping uses to display these vehicles on the map.

DSED Roadway Data – The roadway data used by CHART Mapping (and other CHART applications by extension) is periodically refreshed based on the latest data from the Data Services Engineering Division (DSED). This includes other points of interest such as 911 centers, SHA shops, MSP, bridges, toll plazas, and rail stations.

University of Maryland – The University of Maryland consumes AVL data via the external Mapping REST services.

Maryland Emergency Management Agency (MEMA) – MEMA consumes CHART Mapping data via the external Mapping REST services.

Maryland Transportation Authority (MDTA) – MDTA displays CHART Mapping data (cameras) in Google Earth via a KMZ interface to the external Mapping REST services.

Other Map Data Consumers – There are other external consumers of CHART Mapping REST services. These entities occasionally, or have occasionally in the past, consume Mapping data. These consumers include Frederick County, Howard County, MD 511, USN, SHA.

6 DATA VIEW

6.1 View Description and Typical Stakeholders

This view into CHART Mapping shows how data move into, out of, and around CHART Mapping and describes at a high level how CHART Mapping data is stored in the operational databases associated with CHART Mapping. This view is useful for CHART Mapping DBAs, management, developers, and stakeholders affiliated with the various systems with which the CHART mapping interfaces.

6.2 Data Flow

Data flows for the CHART Mapping are illustrated in Figures 6-1 and 6-2.

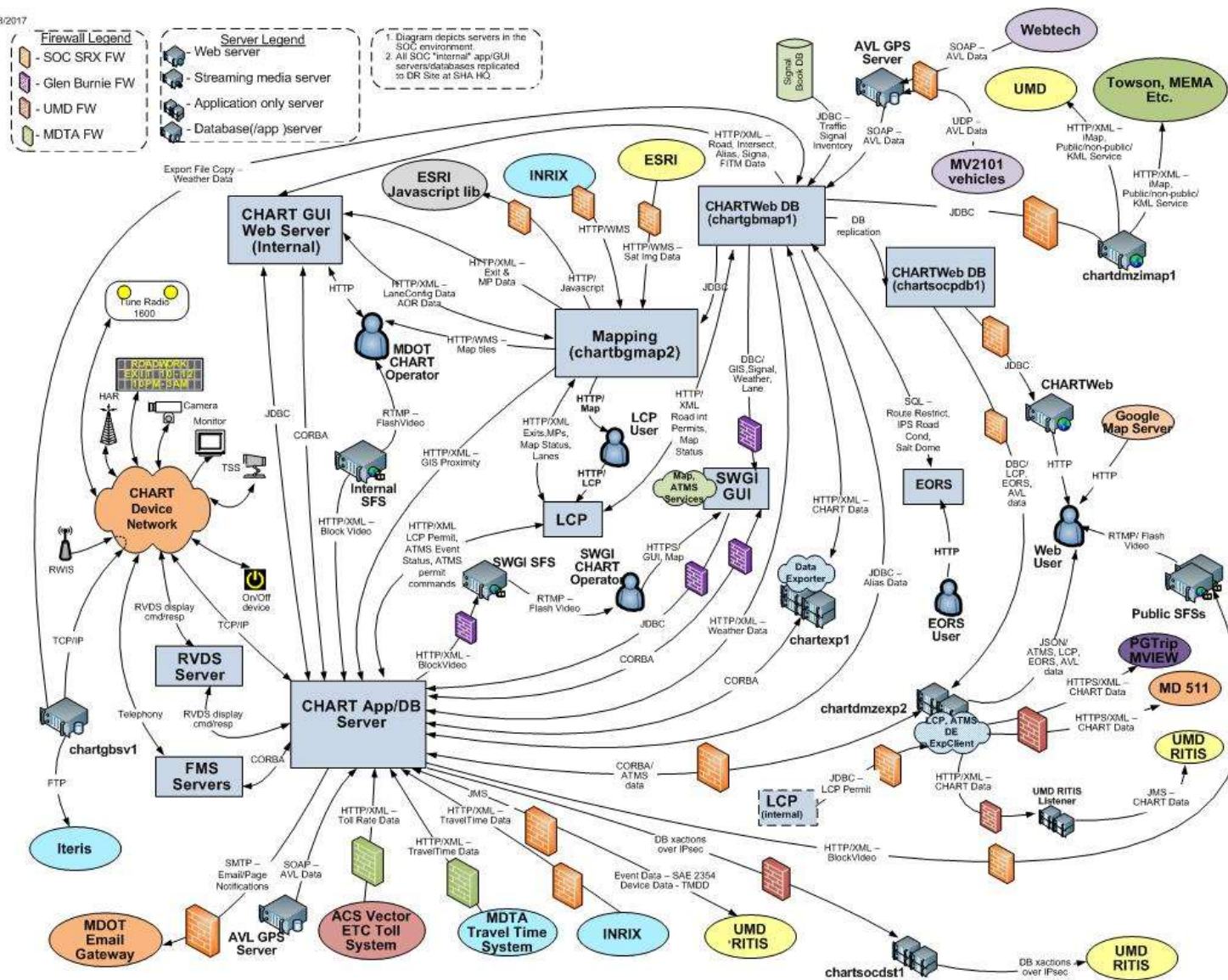


Figure 6-1. CHART High Level Data Flow

6.3 Database

This section describes the CHART Mapping operational database design, at a high level. The database has static and dynamic data, multiple views, stored procedures, functions, database links, and jobs to copy data. The database design consists of these major areas:

- ATMS Traffic Event Viewing (list/map)
- Map events/closures/restrictions
- Static location device data
- Static location ‘Other’ data
- Semi-static data
- Dynamic data
- Static roadway data

6.3.1 ATMS Traffic Event

The ATMS Traffic Event area encompasses Traffic Event related data, including description, type, location, and other attributes by type including lane configuration and status, participants, operation center, and open/close time. This data is operator driven and dynamic as 300+ traffic events are opened each day, with numerous status changes.

6.3.2 Roadway Closure/Restriction data

The Roadway Closure/Restriction area encompasses LCP road closure and EORS Route Restriction data including name, location, and line. LCP data includes lane data and various permit related data as well. This data is operator driven and dynamic. There can be 100+ permit updates each day. Route restriction updates are less frequent.

6.3.3 Static location device data

The static location device area encompasses name and location data representing physical traffic related devices on the roadways. These devices include cameras, DMSs, HARs, SHAZAMs, TSSs, RWIS, Salt Domes, and Signals. This data is entered by operators but is fairly static, changing only when physical roadway devices are deployed, moved, or retired.

6.3.4 Static location Other device data

The static location device area encompasses name and location data representing various points of interest around the state. These include bridges, Maryland State Police barracks, 911 centers, Toll plazas, Light Rail and MARC train stations, SHA shops and garages, and other landmarks.

This data is static and is manually imported into the CHARTWeb database.

6.3.5 Semi-static data

The semi-static data refers to status (rather than location) driven data that is driven by operators. This data includes Area Wide Road Conditions, Snow Emergency plans, and Winter Storm Management Segments. It also includes County summaries. All of these status updates are driven by operator input and may drive fairly frequent updates during winter storm events but are seldom updating otherwise.

6.3.6 Dynamic data

The dynamic data refers to status (rather than location) driven data that is driven by physical roadside devices and systems and can update frequently. This includes video from cameras, AVL data, TSS speed data, INRIX speed data, RWIS data, and Salt Dome balances.

6.3.7 Static roadway data

The static roadway data refers to the roadway related data on the CHARTGB database. This data is static, only changing when updates from HISD are manually applied.

7 DEPLOYMENT VIEW

7.1 View Description and Typical Stakeholders

The deployment view describes the physical locations of servers and services. This view is useful for Operations and Maintenance personnel to identify relationships within and between servers. Network engineers may be particularly interested when identifying which protocols are expected between any pair of servers in the system.

7.2 Deployment Configurations

The nominal CHART Mapping software service configuration is shown in the table below. Note that there are some ATMS components on chartgbmap1, chartgbweb1, chartshahqmap01. Under normal conditions the primary server executes all CHART Mapping services. In a fail-over situation, the failover virtual environment supports all CHART Mapping services. The required COTS packages to support CHART Mapping are also installed on each server per the CHART Mapping Operations and Maintenance Guide.

Table 7-1. CHART Mapping Deployed Services Per Site

Site	Server	Purpose	Service Name
GB-DC	chartgbmap1	Consume AVL Data for display on Map	AVLClient
		Mapping databases	SQLServer
		CHART ATMS Signal Service	SignalService under Apache Tomcat
		CHART ATMS Weather Import Management	WeatherService under Apache Tomcat
		CHART ATMS GUI Alias and Roadway Location/Intersection Lookup	GISService under Apache Tomcat
		CHART ATMS ExportClient	ExportClientService under Apache Tomcat
	chartgbmap2	User Interface	Main Map
		Map Services	CHART_Centerline_Routes (MapServer) CHART_Centerline_Routes (NAServer) CHARTWEB_JS2_FS (FeatureServer) CHARTWEB_JS2_FS(MapServer) CHARTWEB_JS2-QL(MapServer) CHARTWEB_JS2(MapServer) CHARTWeb_TSS (MapServer) CHARTAVL (MapServer)

Site	Server	Purpose	Service Name
		CHART Mapping GIS Service (lane config, milepost & exit lookup, AOR support, FITM, Decision Support)	IIS(GISService/MapGISService.aspx)
		CHART Map Tile Service (background tiles and map layers for exit and milepost tiles)	ArcGIS(CHARTBG_Cache, CHART_Exits_Mileposts_Cache)
	chartdmzimap1	External REST services	iMap iMap_Non_public CHART_Non_Public_KMZ CHART_Public_mobile CHART_Public_PC CHARTAVL_REST
Glen Burnie - TSO	chartgbweb1	CHART ATMS User Interface	chartlite under Apache Tomcat
		CHART ATMS Lane Configuration	LaneEditorService under Apache Tomcat
		CHART ATMS System Monitor	(2) WatchdogService (WatchdogModule)
		CHART Map Tile Service (background tiles and map layers for exit and milepost tiles)	ArcGIS(CHARTBG_Cache, CHART_Exits_Mileposts_Cache)
		CHART Mapping GIS Service (lane config, milepost & exit lookup, AOR support)	IIS(GISService/MapGISService.aspx)
		CHART ATMS Signal Service	SignalService under Apache Tomcat
		CHART ATMS Weather Import Management	WeatherService under Apache Tomcat
		CHART ATMS GUI Alias and Roadway Location/Intersection Lookup	GISService under Apache Tomcat
Baltimore SHA HQ	Chartshahqmap0 1	<failover only> * (See –GB-DC chartsocmap1 for details.)	* (See –GB-DC chartgbmap1 for details.)
	Chartshahqmap0 2	<failover only> *(See –GB-DC chartsocmap2 for details.)	* (See –GB-DC chartgbmap2 for details.)
* Note: Items marked with a * are not normally executed (only during failover/emergency situations).			

7.3 CHART Mapping Network/Deployment Diagram

Figure 7-1 shows the network diagram for CHART, including CHART Mapping.

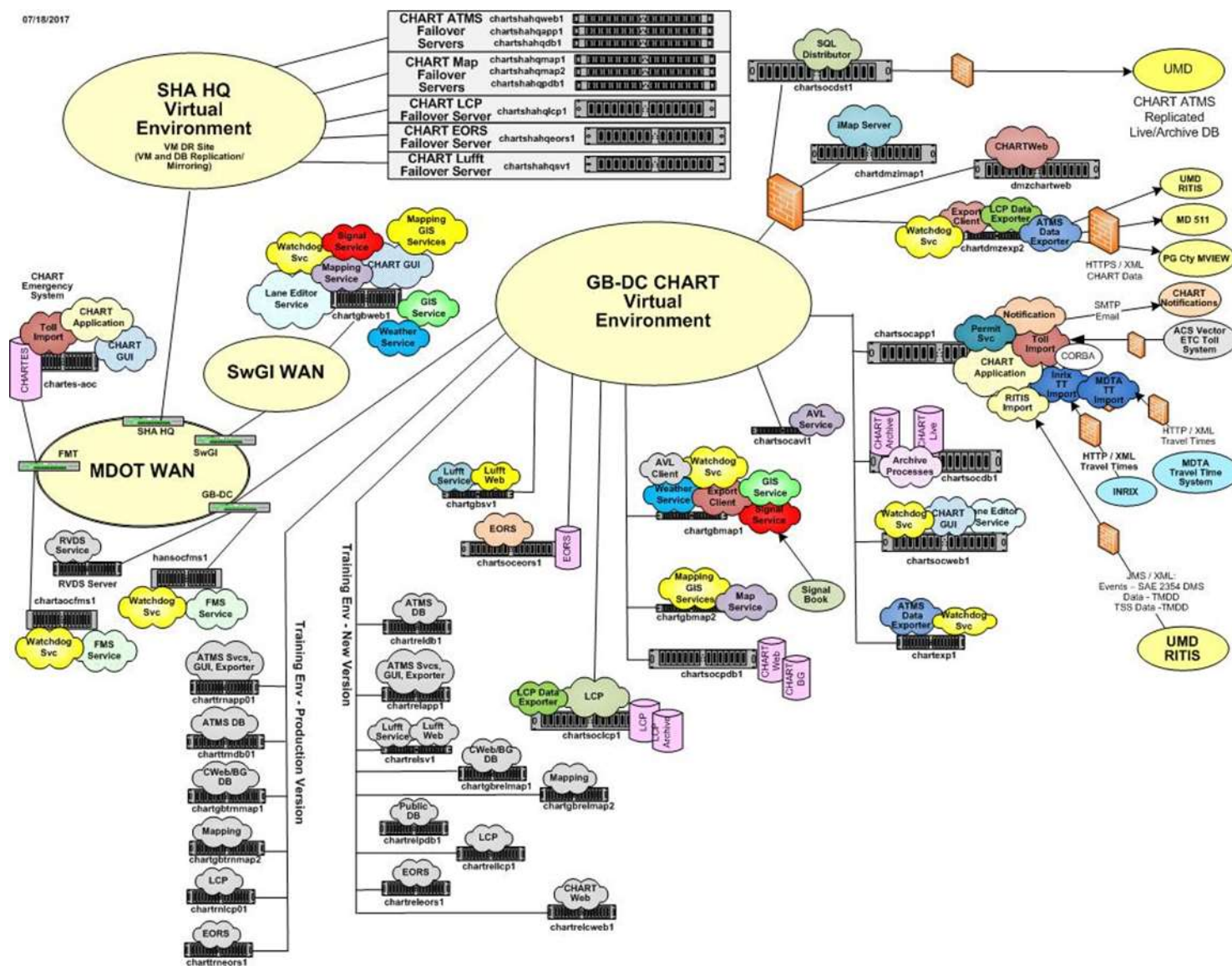


Figure 7-1. CHART Server/Switch Deployment

7.4 Facilities

This section presents the recommended deployment of hardware at each facility.

7.4.1 Node Sites

CHART Mapping database and application servers are primarily located at the MDOT Glen Burnie Data Center (GB-DC). The GB-DC houses the CHART virtual environment and is the central site for the coordination of CHART activities. The list below describes the equipment to be deployed at each site.

1. MDOT Glen Burnie Data Center (GB-DC) –
 - Virtualized CHART Mapping application server
 - Virtualized CHART Mapping SQL Server database server
 - Virtualized CHART Mapping External REST server
2. Glen Burnie - SWGI
 - One CHART ATMS GUI / Mapping Web server
3. SHA Headquarters
 - Virtualized CHART Mapping application server
 - Virtualized CHART Mapping SQL Server database server

7.4.2 Traffic Operations Centers

Each TOC, including the Maryland statewide operations center (SOC), has the capability to run the CHART Mapping GUI on its workstations. The number and configuration of the workstations is determined on a case by case basis depending upon the activity level at the TOC and the available space.

7.4.3 Other CHART ATMS Client sites

The implementation of the SwGI has allowed CHART ATMS Applications to run on agency owned computers on networks that are connected together and protected by firewalls. Previously CHART ATMS would have to extend the MDOT Network to agencies that wanted to use CHART applications and provide workstations. Gradually CHART partners have been converting to SwGI and CHART has been removing workstations. The CHART Mapping components that are utilized by ATMS are also deployed on the SwGI.

7.4.4 Equipment and Vehicle AVL Installation

In addition to CHART interest in AVL, other SHA offices have deployed AVL equipped vehicles (e.g. dump trucks, state and contractor operated snowplows). The actual number of AVL installations has reached several hundred.

7.5 System Management and Support

This section discusses CHART system management activities and support provided for system monitoring and problem tracking.

7.5.1 Data Backup and Recovery

vRanger is used to create snapshots of the virtual machines then copies them to the failover site (Baltimore SHA HQ). The procedures responsible for performing the backups run automatically and require only periodic checks from CHART personnel to verify correct operation.

The system architecture and design minimizes the likelihood of having to recover an entire disk volume. The use of RAID 1 and RAID 5 arrays means that the system can perform self recovery in most instances. A more likely scenario would be the recovery of data due to corruption of some type. By taking periodic snapshots of the mission critical data and maintaining the Virtual Machine (VM) snapshots for a reasonable period of time a corrupted file could be restored to its last uncorrupted state.

7.5.2 System Monitoring

Transportation Business Unit (TBU) personnel monitor CHART Mapping server performance using Veeam ONE.

7.5.3 Problem Identification and Tracking

The CHART project uses the problem tracking tool JIRA to support CHART system problem reporting and tracking. Problems discovered prior to delivery of a release to operations are handled as described in the “CHART Change Management Plan”.

Problems discovered by operations personnel are logged by TBU or NOC personnel in the NOC’s Maximo system. Problems determined to be CHART Mapping software problems are documented in Jira for tracking and resolution.

8 SUBSYSTEM VIEW

8.1 View Description and Typical Stakeholders

The Subsystem View describes the subsystems of the CHART Mapping, their purpose, and how they are used. It describes all the COTS used in the system, and the source, version, usage, and redistributability of all the COTS. This view will be of primary use to developers, configuration managers, and management of CHART.

8.2 Software Subsystems

Table 8-1 lists each software and hardware Configuration Item (CI) and the subsystems comprising the CI. The sections that follow provide functional descriptions for each CI.

The CHART Mapping is dependent upon network services provided through the MDOT backbone network. The management and control of the network is outside the scope of this document.

Table 8-1. CHART Mapping Configuration Items and Subsystems

CI Name	Subsystems
Internal Map REST Services	CHARTWEB_JS2_QL CHARTWEB_JS2 CHART_Centerline_Routes CHART_Exits_Mileposts_Cache CHARTAVL CHARTBG_Cache CHARTWEB_JS2_FS CHARTWEB_TSS
External Map REST Services	iMap iMap_Non_Public CHART_Non_Public_KMZ CHART_Public_Mobile CHART_Public_PC CHARTAVL_REST
Web Services	Lane Config Service GISService MapGISService
AVL Client	AVLClient
Database Instance	Operational DB
COTS	ESRI ArcServer 10.5 ESRI Network Analyst Extension ESRI Web Adapter 10.5 ESRI Javascript APPI 3.9 Microsoft Visual Studio 2013 .NET framework 4.6.2 Microsoft SQL Server 2014 Microsoft SQL Server JDBC Driver Microsoft Windows Subversion Subversion browser TortoiseSVN JIRA

8.2.1 Internal Map REST Services

The software services comprising the Internal Map REST Services CI are briefly described below. The following sub-sections contain all the REST services that are deployed on the CHART ArcGIS server to query layer data from. Each rest service contains a table of layers that it references.

8.2.1.1 CHARTWEB_JS2_QL

This rest service is mainly consumed by the Intranet Map to display entities that are either received from the CHART ATMS or other external sources such as the Salt domes information. It uses the ArcGIS query layers that embed SQL to directly query database tables and views. Spatial information used by a query layer is not required to be in a geodatabase.

8.2.1.2 CHARTWEB_JS2

This rest service is mainly consumed by the Intranet Map to display entities that are received from the CHART ATMS or other spatial information stored in the geodatabase.

8.2.1.3 CHART_Centerline_Routes

This rest service is mainly consumed by the mapping GIS service for decision support. It queries the network data to find the driving directions from a device to the location of the incident, and determines the proximity of the closest exit to the incident.

8.2.1.4 CHART_Exits_Mileposts_Cache

This REST service is mainly consumed by the CHART ATMS GUI to display exits and mile posts cache on the map.

8.2.1.5 CHARTAVL

This REST service is mainly consumed by the Intranet Map to display AVL vehicles locations.

8.2.1.6 CHARTBG_Cache

This REST service is mainly used to generate background map tiles that are used by the CHART ATMS GUI and Intranet Map. The cache is pre-built and stored by ArcGIS.

8.2.1.7 CHARTWeb_JS2_FS

This REST service is mainly used to add new features such as LCP permit and route restrictions point locations and lines into the geodatabase.

8.2.1.8 CHARTWeb_TSS

This REST service is mainly used by the Intranet Map to display information received from speed detectors.

8.2.2 External Map REST Services

The software services comprising the External Map REST Services CI are briefly described below. The following sub-sections contain all the REST services that are deployed on the external CHART ArcGIS server to query layer data from. Each rest service contains a table of layers that it references.

8.2.2.1 iMap

This REST service is mainly consumed by MEMA's public Osprey system although it is available to other consumers

8.2.2.2 *iMap_Non_Public*

This REST service is mainly consumed by MEMA's non-public Osprey system although it is available to other consumers.

8.2.2.3 *iMap_Non_Public_KMZ*

This REST service is mainly consumed by MDTA for viewing cameras in Google Earth.

8.2.2.4 *CHART_Public_Mobile*

This REST service may be consumed by Maryland Department of IT (DOIT), Frederick County EOC Osprey, Howard County, MDTA, US Navy, or SHA although it is not known how widely used it really is.

8.2.2.5 *CHART_Public_PC*

This REST service may be consumed by Maryland Department of IT (DOIT), Frederick County EOC Osprey, Howard County, MDTA, US Navy, or SHA although it is not known how widely used it really is.

8.2.2.6 *CHARTAVL_REST*

This REST service is mainly consumed by the University of Maryland and MEMA's non-public Osprey system although it is available to other consumers.

8.2.3 Web Services

CHART Mapping web services that run in the IIS. These services are mainly used by CHART ATMS or Intranet Map to retrieve spatial data.

8.2.3.1 *Lane Config Service*

This service is queried to retrieve lane configuration on a route at a given location. It also may write user defined lane configurations on a route at a given location.

8.2.3.2 *GISService*

This service is queried to retrieve exits and mileposts along a given route and retrieve FITMs. It also supports proximity related queries related to ATMS Decision Support functionality.

8.2.3.3 *MapGISService*

This service retrieves and stores Area of responsibility (AOR) polygons.

8.2.4 AVL Client

The AVL Client retrieves SHA vehicle GPS data from a front-end GPS server communicating with the GPS provider, Webtech. It writes that data to the CHARTWeb database for display on the Intranet Map and export to external REST consumers. The GPS server get CHART MV1000 and MV2001 data via direct connection.

8.2.5 Database Instance Subsystems

There is only one software subsystem comprising the Database Instance CI. This subsystem is briefly described below.

8.2.5.1 *Operational DB*

This subsystem comprises the live Microsoft SQL Server databases used by CHART Mapping, as well as other applications. There are two databases: CHARTBG and CHARTWeb. The CHARTBG database stores all roadway related data. The CHARTWeb database stores CHART ATMS traffic event and device related data, LCP data, and EORS data.

The CHARTBG and CHARTWeb databases are mirrored to the SHA Headquarters backup site for redundancy purposes.

The CHARTWeb and CHARTBG (mileposts/milepoints data only) databases are replicated to a “public” database server read by the CHART DMZ applications – CHARTWeb and CHART Export Client.

8.2.5.1.1 Mirroring

This subsystem comprises the Microsoft SQL Server functionality that mirrors the CHART Mapping databases between the primary CHART Mapping site located at the MDOT Glen Burnie data Center and the backup CHART Mapping site located at State Highway Administration (SHA) Headquarters in Baltimore. Both the CHARTBG and CHARTWeb databases are mirrored. Mirroring is configured, monitored, and managed by the CHART DBAs.

8.2.5.1.2 Query

This subsystem provides the ability to query the database, for purposes of examining the database and manipulating data in the database, from a program perspective and via the SQL Management Studio, and also, not formally part of the CHART Mapping.

8.2.6 COTS

The COTS CI collects all COTS packages into a single CI for configuration control purposes. This CI is used to track the COTS packages and versions used. Rather than list each subsystem in paragraphs, the COTS packages used throughout the system are described in Table 8-2 below. Package redistributability is designated as Open source, Free (freely available, but without source), or Proprietary (purchased or otherwise restricted). Usage is listed as Development, Runtime, both Development and Runtime, or Administrative. For COTS that is both Development and Runtime, the predominant usage, if that makes sense, is listed first. Administrative usage is listed when the product is not required to build the system, even if the product is a key part of the development effort, such as Sparx Enterprise Architect, which developers use extensively.

Table 8-2. COTS Packages

Product Name	Version	Description/Purpose	Redistributability	Usage
ESRI ArcGIS Desktop	10.5	CHART Mapping uses ArcGIS Desktop to create ESRI Map documents to be published on ESRI Map server.	Proprietary	Development Runtime
ESRI ArcGIS Server Advanced Enterprise (includes javascript API)	10.5	CHART Mapping uses ESRI Map server and ArcSDE for geodatabase.	Proprietary	Runtime
ESRI ArcGIS Server Network Analyst extension	10.5	CHART Mapping uses ESRI Network Analyst for generating driving directions.	Proprietary	Development Runtime
ESRI Web Adapter	10.5	CHART Mapping uses ESRI Web Adapter to serve external REST services on a well-known HTTP port.	Proprietary	Runtime
JIRA	6.4.11	The CHART Program uses JIRA for tracking problem reports (PRs)	Open source	Administrative
Microsoft SQL Server	2014	CHART Mapping uses Microsoft SQL Server 2014 to host its databases. It uses the same version for retrieving roadway location, weather, and traffic signal data from CHART Mapping and lane closure permits from LCP. The reporting component EORS v2 uses SQL Server 2005.	Proprietary	Runtime
Microsoft Visual Studio (including .NET 4.6.2)	2012 Ultimate	CHART Mapping uses Microsoft Visual Studio 2012 Ultimate for C# source code development. Necessary library files are used in the runtime environment.	Proprietary	Development Runtime
Microsoft Windows	2012 Server	CHART Mapping uses Microsoft Windows 2012 Server as its standard runtime platform for the CHART Mapping application and database servers.	Proprietary	Runtime
RedGate SQL Backup Pro	6	CHART Mapping uses these parts of the RedGate DBA Bundle monitoring tools to support the backup and restore processes and to monitor database performance	Proprietary	Runtime
RedGate SQL Monitor	2.3.0			

Product Name	Version	Description/Purpose	Redistributability	Usage
Sparx Enterprise Architect	9.3.934	CHART Mapping developers use Enterprise Architect by Sparx for UML modeling and design tool.	Proprietary	Administrative
Subversion	1.6	CHART Mapping uses Apache Subversion for source code control.	Open source	Development
Subversion browser TortoiseSVN	1.6.15	Official CHART ATMS builds use TortoiseSVN subversion browser. Some developers may use TortoiseSVN as well.	Open source	Development
vRanger Backup & Replication	5.3.1	The CHART Program uses vRanger Backup & Replication by Quest Software to maintain system backups. This subsystem is not part of the CHART Mapping per se, but serves in a support role. Therefore it is listed as having Administrative usage, rather than Runtime usage.	Proprietary	Administrative
XML Spy	2009 Pro SP 1	CHART Mapping developers use XMLSpy to visualize, edit, and generate XML and XSLT used by the CHART Mapping and by some of the external systems which interface with the CHART Mapping.	Proprietary	Development

9 STANDARDS VIEW

9.1 View Description and Typical Stakeholders

This view into the CHART Mapping describes how the CHART Mapping supports interoperability through ESRI ArcGIS. As such, it is not the Mapping application, but rather the ESRI platform on which it runs supports these standards. This view is useful for MDSHA management, CHART Mapping developers, and those looking to interface with CHART Mapping for the purpose of consuming/display CHART Mapping data.

9.2 Standards Overview

The CHART Mapping application sits on the ESRI ArcGIS platform. ArcGIS supports a number of interoperability standards that are described below.

ArcGIS supports multiple approaches to interoperability:

- Web—SOAP, XML, REST, JavaScript™, KML, Virtual Earth™
- OGC—GML, WFS, WMS, WCS
- Enterprise Integration—SOAP, XML, EJB, SQL
- Application Content—CAD, Image, PDF

9.2.1 OGC WMS and ISO 19128 WMS

WMS is an open GIS standard specification for interactive mapping based on requesting map images from a server over the Internet.

Using WMS with the ArcGIS product family:

- Users can access WMS services containing large numbers of layers over the Internet and add them to their maps as layers.
- WMS services are expandable to enable drilling into layers and layer collections for use directly in maps or globes.
- WMS legends can be added to a map as a graphic.

WCS is a data service that allows users to publish coverages on the Web. Using the WCS specification with the ArcGIS product family

- Clients can get subsets of the data.
- Clients can request server-side re-sampling of the data.
- Geoprocessing models can be published that consume WCS services

9.2.2 OGC WFS

WFS is a service that allows users to publish vector feature collections that may be queried and updated by clients. ESRI supports the simple features profile of GML and both the read-only and transactional (WFS-T) version of the WFS specification. WFS-T allows any GIS client to carry out transactions against a published geodatabase.

9.2.3 KML

KML is an XML-based file format used to represent geographic features in Web-based applications such as ArcGIS Explorer.

- Maps and layers can be converted to KML and read by any client capable of reading KML.
- Map and image services expose a KML network link through a Representational State Transfer (REST) interface.
- Clients can query map layers or perform a geoprocessing or geocoding operation and obtain the results as KML.
- Clients can consume published ArcGIS Server KML services for dynamic maps that show the latest information

10 BUSINESS ARCHITECTURE VIEW

10.1 View Description and Typical Stakeholders

This section provides a view into how the CHART Program aligns with the CHART Business Area Architecture, which lays out the business case and business objectives for CHART, and attempts to align those with current and desired future capabilities. This section lays out a business strategy for achieving those goals, in line with available and long-term resources. Interested stakeholders would include MDSHA management and CHART Program Management, especially those who participated in the BAA process, or those would like to learn more about CHART's business plan and its mapping to CHART capabilities.

10.2 Business Area Architecture

Since the BAA is largely ATMS focused, there are no requirements in the BAA satisfied by CHART Mapping alone. However, CHART Mapping does support many of the BAA requirements met by ATMS. In particular CHART Mapping contributes to requirements met in the areas of:

- Administer systems and equipment
 - o Administer CHART organizations, locations, and users
 - Maintain CHART organizations and geographic areas of responsibility
- Prepare for events and emergencies
 - o Maintain decision support plan
 - Select DS Plans and conditions
 - Associate DS devices to DS plan
 - Associate FITM or alternate route
- Manage events
 - o Open event
 - Record event details
 - Specify location and impact

Figure 10-1, from the BAA, summarizes the Business Process Model. For more detail, see the full breakdown in Appendix B of the CHART Business Area Architecture.

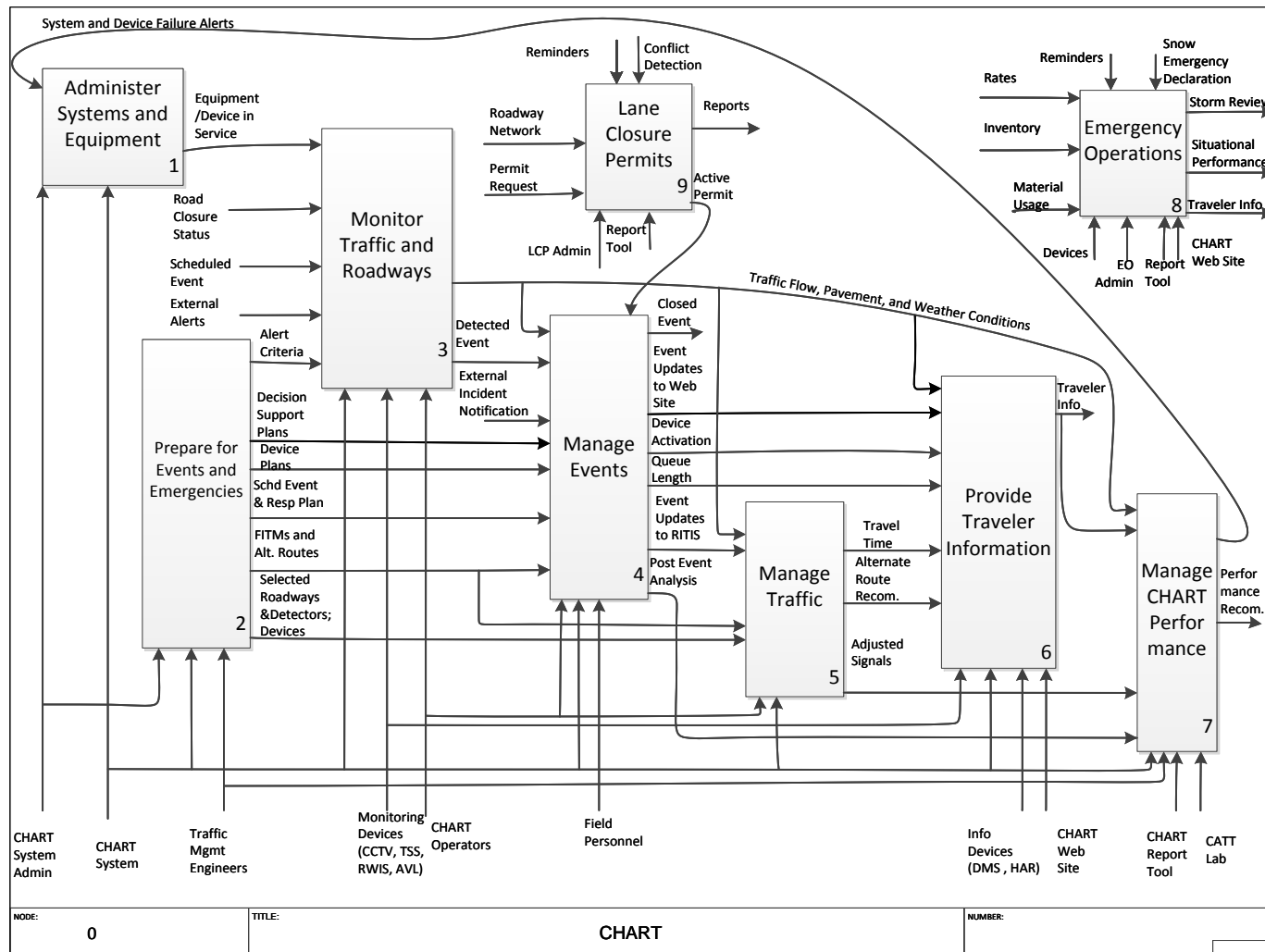


Figure 10-1. CHART High Level Business Process Model

10.3 Future CHART Mapping Releases

Below is the future mapping functionality as known.

Table 10-2 CHART Mapping Future Release Functions

CI	Subsystem	Function
CHART Mapping	IntranetMap/MapServices/ REST	DSED Data Handling Reduce Deployment Downtime Updated Lane Configurations
CHART Mapping	IntranetMap/MapServices/ REST	Conflate Map Data Update Data for all Maps

10.4 Near Term Goals

10.4.1 TBD

TBD.

11 SYSTEM MAINTENANCE VIEW

11.1 View Description and Typical Stakeholders

This section provides a view into the high level CHART Mapping maintenance tasks. This includes system maintenance (including backup and recovery), database maintenance, and routine software maintenance. It also includes periodic roadway data maintenance. The CHART Mapping Operations and Maintenance Guide contains much more detailed information on these routine maintenance tasks. Interested stakeholders would be system administrators, software and system architects, and any other parties interested in a high level view of maintenance tasks for the CHART mapping.

11.2 Data Backup and Recovery

Data backup and recovery are implemented at both the system level and the database level. Database level backups are needed in order to guarantee transactional integrity and to prevent database backup corruption.

11.2.1 Data Backup

11.2.1.1 Virtual Environment

Procedures for backing up the virtual environment are not covered in the CHART Operations and Maintenance Guide. These tasks are performed by Transportation Business Unit (TBU) personnel following procedures maintained by TBU staff. Most of these procedures can be found in the CHART Virtualization Operations and Maintenance Guide.

The ability to “snapshot” a virtual server provides the ability to roll back a server to a previous state should an issue occur with that server, and simplifies maintenance and administration by allowing patches and upgrades to be easily and quickly backed out if necessary.

Full image snapshots are taken nightly and copied to an offsite location at SHA Headquarters (HQ) in Baltimore. Included in these snapshots are local snapshots with file and image-level restore functionality.

11.2.1.2 Database

Database backup tasks and the procedures for executing those tasks are detailed in the CHART Mapping Operations and Maintenance Guide. There are procedures for both the CHARTBG and CHARTWeb databases. Backup jobs are run using the SQL Backup tool by Redgate. Those tasks include:

- Full database backup

- Transactional database backup

- Differential backup

In addition, the CHART Mapping databases are mirrored from the MDOT Glen Burnie Data Center (GB-DC) to the backup site at SHA HQ. The database mirroring procedures are described in the CHART Mapping Operations and Maintenance Guide. The mirrored databases can be recovered to the prime site at the GB-DC or utilized at SHA HQ in a failover scenario.

11.2.2 Data Recovery

11.2.2.1 Virtual environment

The site at SHA HQ exists as a redundant and disaster recovery capable location where individual pieces or the entire suite of CHART applications (CHART ATMS, CHART Mapping, LCP, etc.) can exist if necessary. All CHART servers may be instantiated at SHA HQ, including both the CHART Mapping servers and other servers within the CHART enterprise, including a number of applications that CHART Mapping interfaces with. Should a full site recovery at SHA HQ be necessary, all non-database data would be recovered within a datastore replication window. For the CHART Mapping itself, all relevant data is stored in the database and the database recovery process is executed as an additional step after servers have been instantiated at SHA HQ.

11.2.2.2 Database

Database recovery can be accomplished through these mechanisms as detailed in the CHART Mapping Operations and Maintenance Guide:

- Recovering database backup

- Recovering mirrored database from SHA HQ

- Utilizing mirrored database at SHA HQ

11.3 System Monitoring

Cern Virtual Infrastructure (CVI) administrators will access the environment through a variety of tools, depending upon the task and required method of access.

11.3.1 Virtual environment

The vSphere Web Client provides the most comprehensive access to the VMware environment, allowing administrators to add, delete, modify, move, and monitor the physical and virtual machines. “Console” access is granted through this tool, as well as providing basic monitoring and environmental health visible through the client. A traditional “thick” client may be downloaded via web browser using the address of the vCenter server, one of the individual hosts, or from www.vmware.com.

A Secure Shell (SSH) client, such as Putty, may be used for access into the root console of the VMware hosts for administration or maintenance that is not available within the vSphere Client. This typically is used for application of hotfixes and upgrades to the physical hosts, detailed log viewing, or high-level administrator activities.

Veeam provides monitoring capabilities with limited access to virtual machines and physical hosts. Veeam is accessed via web browser through a specific port for both monitoring and configuration. Veeam is used to monitor CPU usage, memory usage, disk usage, and I/O statistics, etc. Veeam can generate alarms and notifications based on defined thresholds.

Integrated Lights-Out (iLO) provides access to the HP hardware, which can be managed from the Blade Enclosure management connection, or from a web browser pointed to the correct IP address. In addition, hardware can be managed from a Liquid Crystal Display (LCD) screen on the front of the blade enclosure, directly connecting into the blade via a

dongle connection, or through keyboard-video-mouse (KVM) switch connection to the Storage Area Network (SAN) or Blade hardware.

11.3.2 Database

Database backup jobs are monitored using Red Gate SQL Backup tools. These tasks are detailed in the CHART Mapping Operations and Maintenance Guide. Specific tasks include:

- Observing last backup run time and status

- Check of physical file backup on the appropriate server

The database mirroring process is also monitored using Red Gate tools. These procedures also are described in detail in the CHART Mapping Operations and Maintenance Guide.

11.4 High Availability

The CHART system design provides high availability through these methods.

- Redundancy within virtual environment

- Redundancy of communications paths

- Database mirroring

- Offsite backup capabilities for CHART Mapping and the entire virtual environment

Each of these methods will be discussed in more detail below.

11.4.1 Redundancy within the Virtual Environment

The CHART Virtual Infrastructure provides redundancy through the implementation of a cluster of hardware and software packages.

The CHART Virtual Infrastructure provides redundancy through the implementation of a cluster of hardware and software packages.

- Storage is provided by a SAN cluster with redundant network connections accessible by all devices. This storage is replicated regularly to the SHA HQ site. The current configuration allows several individual component failures within the SAN without loss of data or the need to fail over, as well as the ability to perform file-level recovery and full image restoration if needed.

- Hardware hosting the virtual servers provides protection against data and service loss with several components having 100% redundancy. For instance, the “Flex 10 networking modules” are completely redundant. The physical hosts themselves can tolerate the loss of 1/3 of the available physical hosts and still maintain full capabilities when the impacted virtual hosts are moved to the remaining physical hosts(s).

- Network and power redundancy are also at 100% with the ability to lose a full network or power feed without adversely affecting the environment.

- VM Application and hardware configuration provides automatic failover of many components, including the ability to distribute resources, re-locate virtual servers on demand, take snapshots of servers prior to updates/upgrades, etc.

11.4.2 Redundancy of Communications Paths

There are redundant or backup communications paths for the CHART Backbone network traffic.

11.4.3 Database Mirroring

SQL Server mirroring has been established between the databases at the principal node at the MDOT Glen Burnie Data Center and mirror node at the SHA HQ data center. Both the CHARTBG and CHARTWeb operational databases are mirrored. Two identically configured servers reside at each of the nodes from both a hardware (virtual) and software perspective.

As database transactions are committed in the principal node these transactions are copied over to the mirror node. The copying happens in real time and the data is in a synchronized state between the nodes. The level of synchronization can be set to be either dual commit or single commit mode. In a dual commit mode the database transaction is written to both nodes and only then will the relevant locks be released. In a single commit synchronization mode, transactions are committed at the principal node and locks are released. As a follow-on action these transactions are forwarded to the mirror node.

The CHART Mapping database is configured in a single commit synchronization mode. In a future release, the CHART Mapping application could be modified to take advantage of automatic failover, in which case the dual commit synchronization mode with automatic failover could be used.

In case of a database failure at the principal node, the CHART ATMS database will be manually failed over to the mirrored node. A pre-configured CHART ATMS application installation exists at the mirrored node to point to the mirrored database. This allows failover to a secondary site in minimal time as the data will be copied in real time to the secondary site.

11.4.4 Offsite Backup Capabilities for the Virtual Environment

Full image snapshots are taken nightly and copied to the SHA HQ location in Baltimore. Included in these snapshots are local snapshots with file and image-level restore functionality.

The site at SHA HQ exists as a redundant and disaster recovery capable location where individual pieces or the entire CHART system can exist if necessary. Currently, the entire CHART network at the GB-DC can be failed over to SHA HQ. Details are provided in the CHART Virtualization Operations and Maintenance Guide. It is also possible for just CHART Mapping to be run at SHA HQ, although there are few if any scenarios where this would be beneficial.

Details of the CHART Mapping manual failover procedure can be found in the CHART Mapping Operations and Maintenance Guide.

Additional details on CHART Mapping failover to SHA HQ can also be found in the CHART Mapping Application Recovery Plan.

11.5 CHART Mapping Administrator Maintenance Tasks

There are a number of routine maintenance type tasks that can be performed using the ESRI ArcGIS Desktop tool set. These are most likely to be performed by software development staff although the CHART Mapping Operations and Maintenance Guide has sufficient detail to allow others to perform these tasks.

“Device” Editor. This includes adding, editing and deleting Roadway Weather Information Systems (RWIS) and FITMs.

External REST user/role maintenance. This includes adding, editing, and deleting user logins needed for accessing the external REST services. It also includes defining the roles (access) that users are attached to.

11.6 Software Distribution

This section presents the procedures and processes used to control and manage the development and distribution of the CHART Mapping software.

11.6.1 Configuration Management and Version Control

The overall Configuration Management (CM) plan for CHART is presented in the document *CHART Change Management Plan*. The specific objectives of the CHART CM program are to ensure that:

- CHART hardware, software, and data configuration items (CIs) are appropriately selected and identified

- CHART project baselines are established at the correct time

- Changes to the CHART baselines are authorized, evaluated, implemented as approved, verified, and tracked in accordance with established procedures

- Commercial off-the-shelf (COTS) tool upgrades are fully assessed and their impact evaluated

- The status of CHART baselines and proposed and approved changes is accounted for and reported

- Baseline and other required CM audits are carried out and the results reported

- The integrity of the system design is maintained

- The delivered system and all accompanying deliverables are accurately defined and described

The CHART Mapping development team is using Subversion as the configuration management tool to support CHART Mapping software development. The configuration management policies and procedures for the CHART Mapping software are defined in a set of standards and procedures documents. These standards and procedures documents are listed below.

CHART Change Management Plan

11.6.2 Software Installation

The installation of new versions of CHART Mapping software components is controlled as described in the *CHART Change Management Plan*. The detailed plan for executing the installation is contained in the CHART Mapping Implementation Plan that is customized for each CHART Mapping software release. For new site installations the software components are installed and configured prior to integration of the system into the operational environment. Appendix A of the CHART Mapping Operations and Maintenance Guide presents instructions for performing software installations on operational system components. This includes installation of both COTS and of the CHART Mapping software proper.

11.7 Training

Training of CHART operations staff in the use of the CHART Mapping is provided via several means.

CHART Mapping can be installed in a training environment where users can operate the system without interfering with production.

A training plan is developed for each CHART Mapping software release. Training sessions are conducted by MDSHA at their discretion.

LIST OF ACRONYMS

The following table lists the acronyms used in the document.

Acronym	Description
AOC	Authority Operations Center
AOR	Area of Responsibility
API	Applications Programming Interface
ATMS	Advanced Traffic Management System
AVL	Automatic Vehicle Location
BAA	Business Area Architecture
BHT	Baltimore Harbor Tunnel
CATT	Center for Advanced Transportation Technology
CCTV	Closed Circuit Television
CHART	Coordinated Highways Action Response Team
CM	Configuration Management
COTS	Commercial Off-The-Shelf
CVI	Cern Virtual Infrastructure
DB	Database
DBA	Database Administrator
DCDOT	District of Columbia Department of Transportation
DMS	Dynamic Message Sign
EORS	Emergency Operations Reporting System
ER	Entity Relationship
ERD	Entity Relationship Diagram
ESRI	Environmental Systems Research Institute
FC	Fibre Channel
FITM	Freeway Incident Traffic Management
FMT	Fort McHenry Tunnel
FSK	Francis Scott Key [Bridge]
GB-DC	MDOT Glen Burnie Data Center
GUI	Graphical User Interface
HA	High Availability
HAR	Highway Advisory Radio

Acronym	Description
HIS	Highway Information Systems
HISD	Highway Information Services Division
HP	Hewlett-Packard
HQ	Headquarters
HTTP	Hyper Text Transfer Protocol
HTTPS	Hyper Text Transfer Protocol Secure
I	Interstate
ICD	Interface Control Document
iLO	Integrated Lights-Out
IP	Internet Protocol
iSCSI	Internet Small Computer System Interface
ISDN	Integrated Services Digital Network
JSON	JavaScript Object Notation
KVM	Keyboard-Video-Mouse [Switch]
LCD	Liquid Crystal Display
LCP	Lane Closure Permits
MD	Maryland
MD511	Maryland 511 (Maryland's 511 Traffic information System)
MDOT	Maryland Department of Transportation
MDSHA	Maryland State Highway Administration
MDTA	Maryland Transportation Authority
NOC	Network Operations Center
NTCIP	National Transportation Communication for ITS Protocol
PR	Problem Report
REST	Representational State Transfer
RITIS	Regional Integrated Transportation Information System
RSS	Really Simple Syndication
RTMS	Remote Traffic Microwave Sensor
SAN	Storage Area Network
SCSI	Small Computer System Interface
SFS	Streaming Flash Server
SHA	State Highway Administration
SHAZAM	Sign with controllable beacons to indicate a message of significance is playing on a

Acronym	Description
	nearby HAR. (SHAZAM is not an acronym.)
SOC	Statewide Operations Center
SOP	Standard Operating Procedure(s)
SP	Service Pack
SSH	Secure Shell
SSP	Safety Service Patrol
SwGI	Statewide Government Intranet
TCP	Transmission Control Protocol
TOC	Traffic Operations Center
TSS	Transportation Sensor System
UMD	University of Maryland
US	United States
vCPU	Virtual CPU
VM	Virtual Machine
WAN	Wide Area Network
WMS	Web Map Service
WYSIWYG	What You See Is What You Get
XML	Extensible Markup Language

A DESIGN STUDIES

This section provides information on analysis, prototyping, and trade studies dating from the initial system design effort to the current time.

A.1 CHART Systems Database Strategic Plan

The purpose of this study, completed in April 2011, was to identify database options for the full CHART Program that would maximize technical and financial benefit to SHA's business goals. The subsequent CHART Work Order Scope and Estimate Request Form requested the production of a white paper document to recommend a 5 year strategic plan for the CHART systems databases and also, after a checkpoint with SHA, to create a plan including a schedule, assumptions and risks to implement the approved recommendations.

The assessment was approached using the Enterprise Architecture Framework as defined by the National Institute of Standards and Technology. This approach gives a holistic view of the enterprise. The Enterprise Architecture has 5 layers. The five layers are:

- Enterprise Business Architecture Layer
- Enterprise Information Architecture Layer
- Enterprise Application Architecture Layer
- Enterprise Application Integration Architecture Layer
- Enterprise Infrastructure Architecture Layer

The Enterprise Business Architecture Layer review for SHA was carried out previously by CSRA and is reflected in the Business Area Architecture document: BAA Report Revision 6, January 2011. The recommendation for this layer was to continue on those specified in BAA.

The Enterprise Information Architecture Layer is comprised of the Presentation Management and Reports Management layers. In the Presentation Management layer of SHA, there are several Graphical User Interfaces identified. These are CHART GUI, EORS V2 GUI, LCP (known as EORS Legacy at the time) GUI, CHARTWeb Desktop, and the Intranet Map. The recommendation for this layer was to establish a single EORS (LCP) GUI, establish CHART Analytics GUI, establish an Attention Admin GUI and continue to use the following GUIs; CHARTWeb Desktop, CHART GUI, Intranet Map (ArcGIS) and implement a portal tool that will unify and enable a role-based Single-sign on.

In the Reports Management portion of the Enterprise Information Architecture, several report conduits were identified: SREE, SQL Server Reporting Service, Legacy Reporting Service, and Google Web Analytics Lite. The recommendation for this layer was to retire SREE, consolidate all SQL Server Reporting services, establish CHART dashboards, CHART Analytics (Business Intelligence tool) and use Google Urchin.

The Enterprise Application Architecture Layer is comprised of four core applications, which are the CHART ATMS, LCP (EORS at that time), CHARTWeb and CHART Mapping. The recommendation at this layer was to continue to have the applications remain independent of each other and integrate in the middleware layer.

The Enterprise Application Integration Architecture Layer is comprised of the middleware/IPC management layer. The CHART middleware management is using CORBA, Apache Tomcat, IIS, ASP, .NET, RSS, XML Web Services, and REST Web Services. The recommendation for this layer was that CHART is already on a good path and should continue to

use Tomcat, IIS, ASP, .NET, RSS, and Apache. It was recommended that CHART implement an Enterprise Service Bus (ESB), establish web orchestration using BPEL, establish a form of Workflow mechanism using BPM, and establish a Web Services Manager and Service Registry. These middleware upgrades could possibly lead to the replacement of CORBA as an IPC solution for the CHART ATMS at some point in the future.

The Enterprise Infrastructure Architecture Layer is comprised of Database Management; Archive and Backup Management; and the physical Infrastructure Management. The recommendation for the Database Management portion was for SHA to use web services for communication and take the “Federated Option” which consists of the following components:

- Attention Database (paging system)

- A consolidated CHART Database

- CHART BG Database (SDE & Mapping)

- A consolidated database for LCP (EORS at that time)

- CHART Web Cache Database

- CHART Analytics Database (CHART-A)

This recommended approach would give SHA flexibility for growth, while systems and development cycles remain independent. It also provides a quicker patching cycle and keeps all application communication at the middleware layer. At the database layer, the recommendation is to consolidate databases where possible and implement an enterprise data governance strategy. The recommendation for the physical Infrastructure Management portion is for SHA to continue on the path of establishing VMware ESXi and upgrading to a more recent version of the Windows Server operating system. The ArcServe Backup product recommended by CHART’s infrastructure team will be implemented

B DATABASE DETAILS

This appendix provides Entity Relationship Diagrams (ERDs) for the database schema used in current release of CHART Mapping. Figures B-1 through B-7 contains the ER diagram for the CHARTBG database in 7 pieces. Figures B-8 through B-16 contains the ER diagram for the CHARTWeb database in 9 pieces. The ER diagram pieces are laid out such that as few lines as possible connect from one page to another, but some interpage connections (relationships) are unavoidable. The figures are numbered so that if they were placed in a 3x3 grid, with ERD Page 1 in the upper left corner, ERD Page 2 to its right, page 3 to its right, Page 4 second row far left, etc. They would form one large picture with lines connected across the individual pages where necessary.

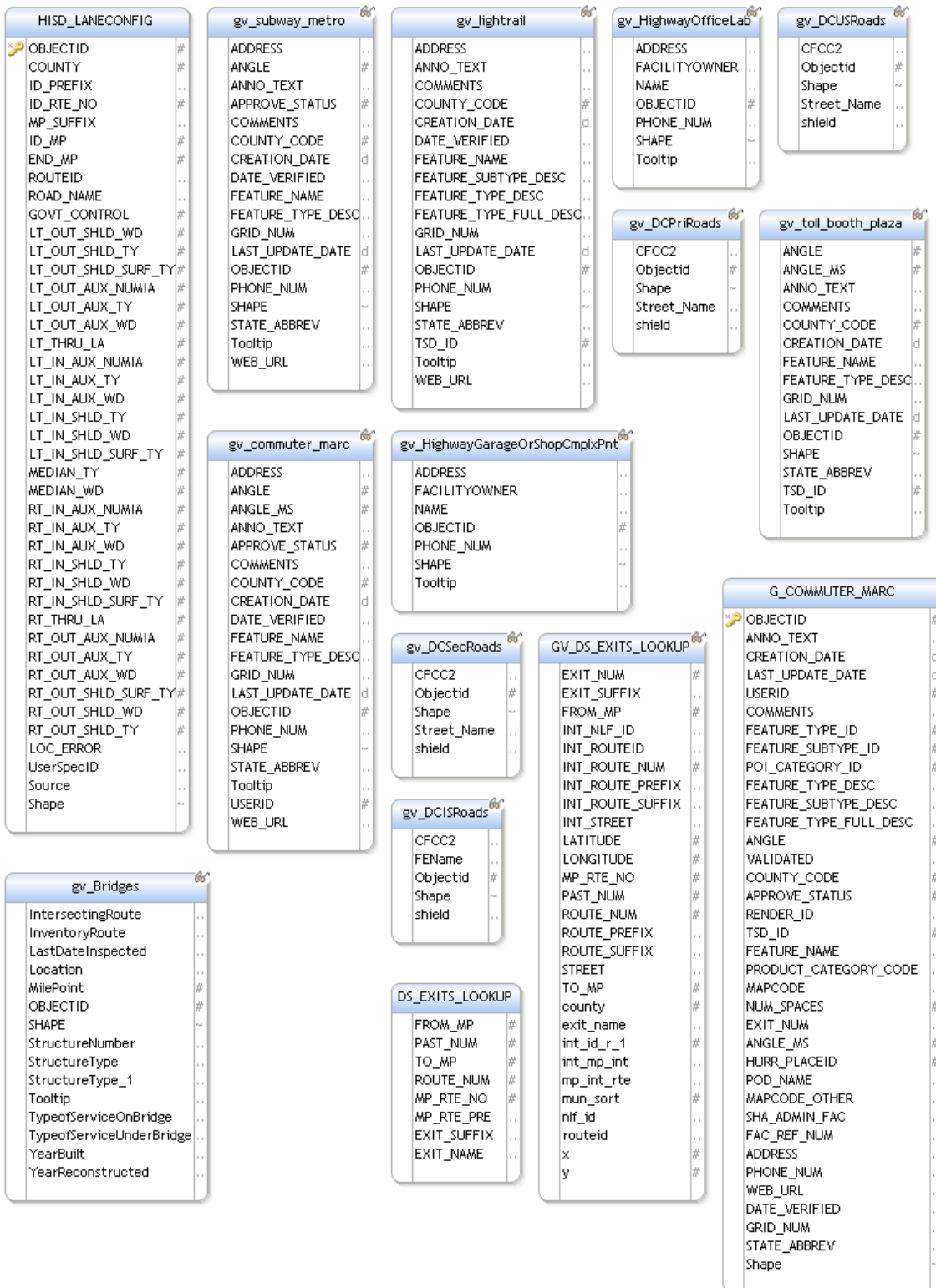


Figure B-1. CHARTBG ERD Page 1



Figure B-2. CHARTBG ERD Page 2

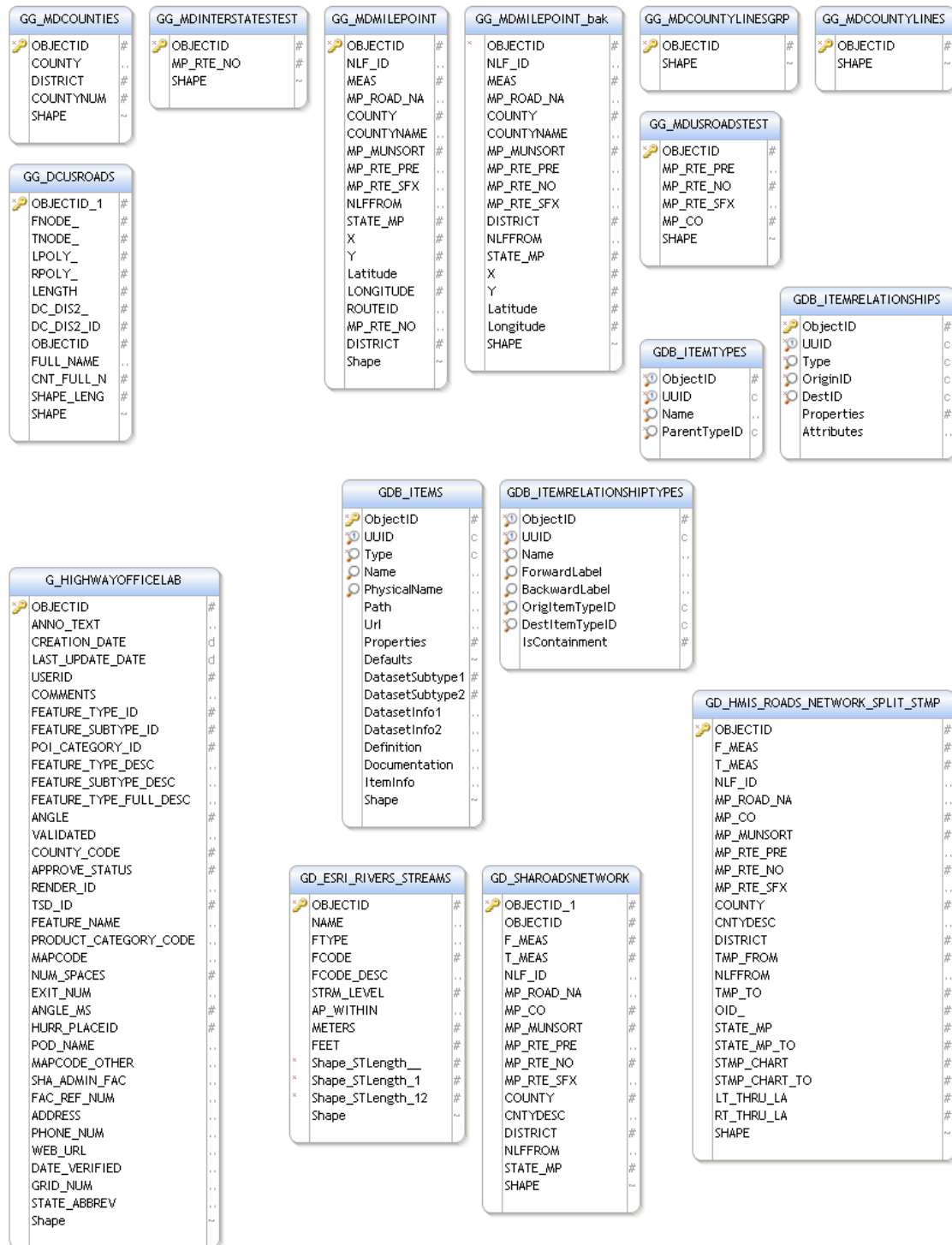


Figure B-3. CHARTBG ERD Page 3

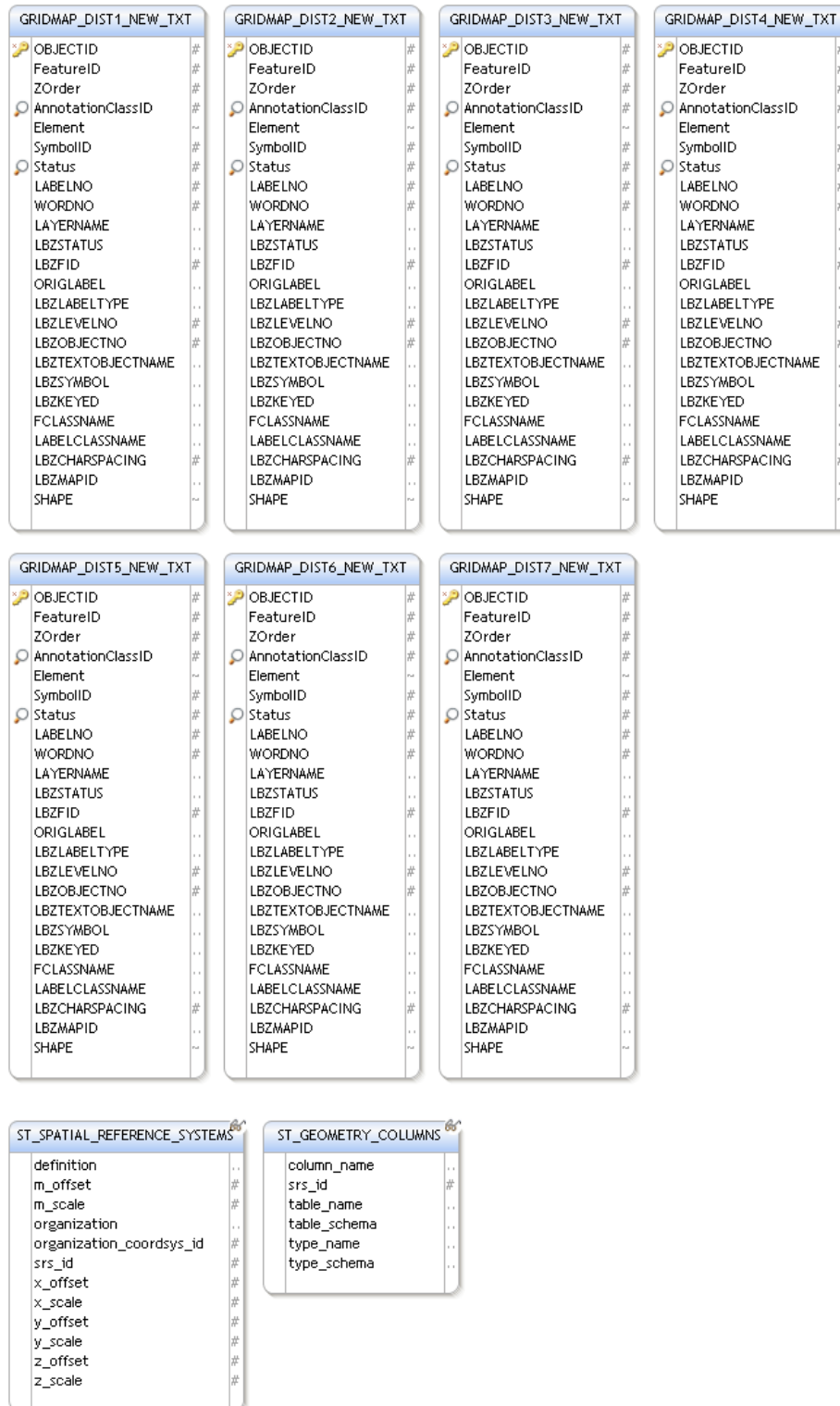


Figure B-4. CHARTBG ERD Page 4

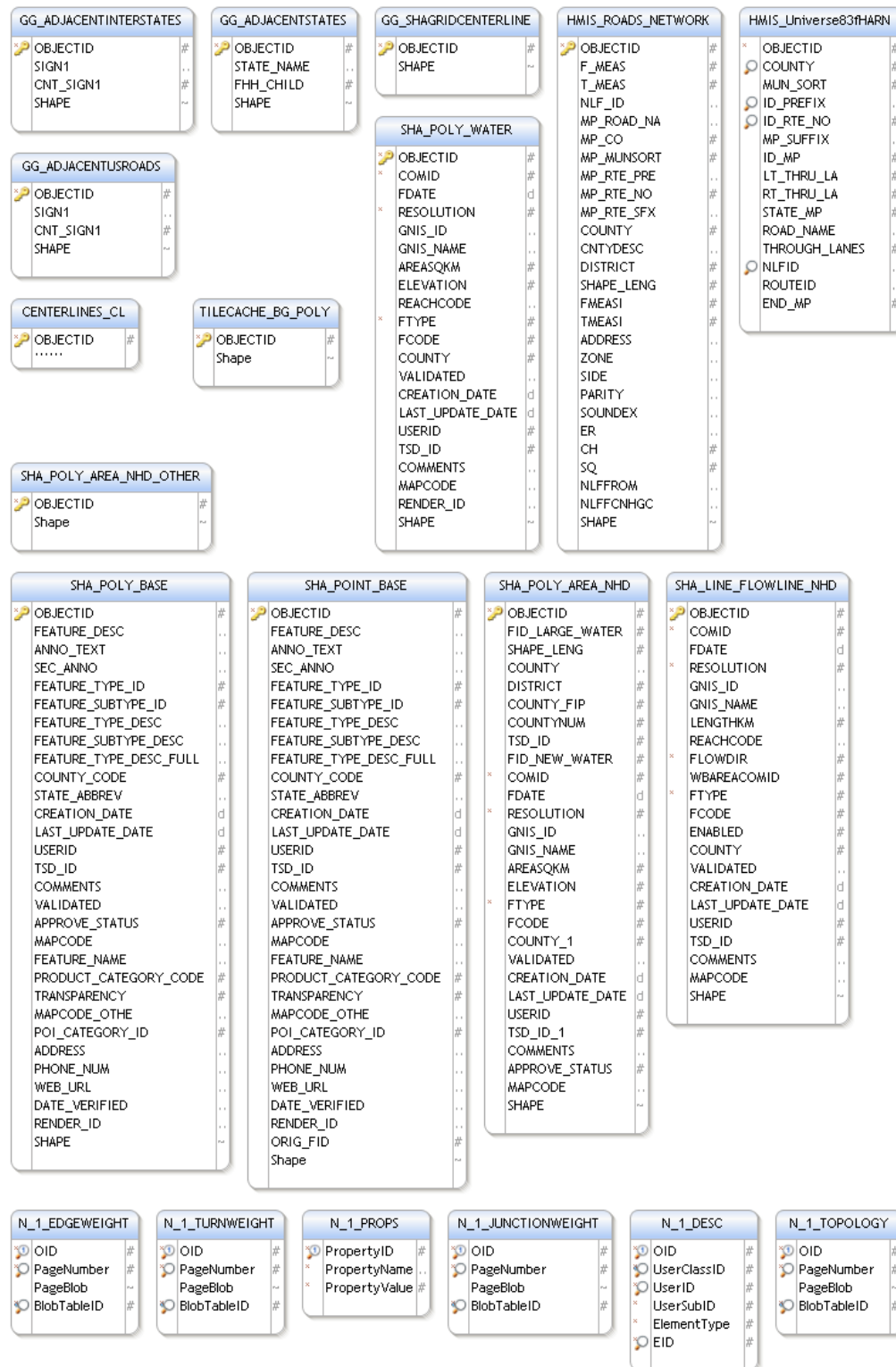


Figure B-5 CHARTBG ERD Page 5

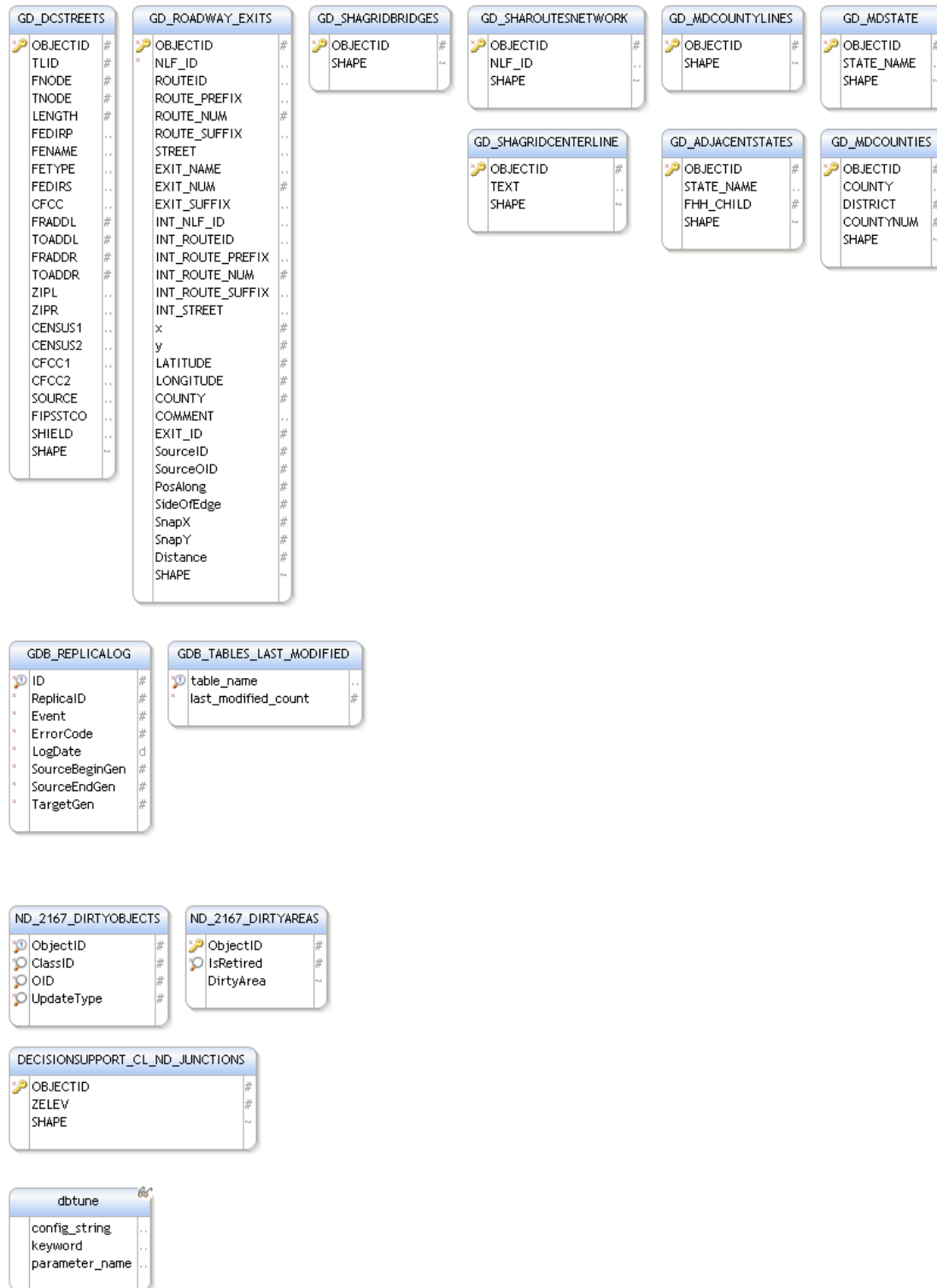


Figure B-6. CHARTBG ERD Page 6

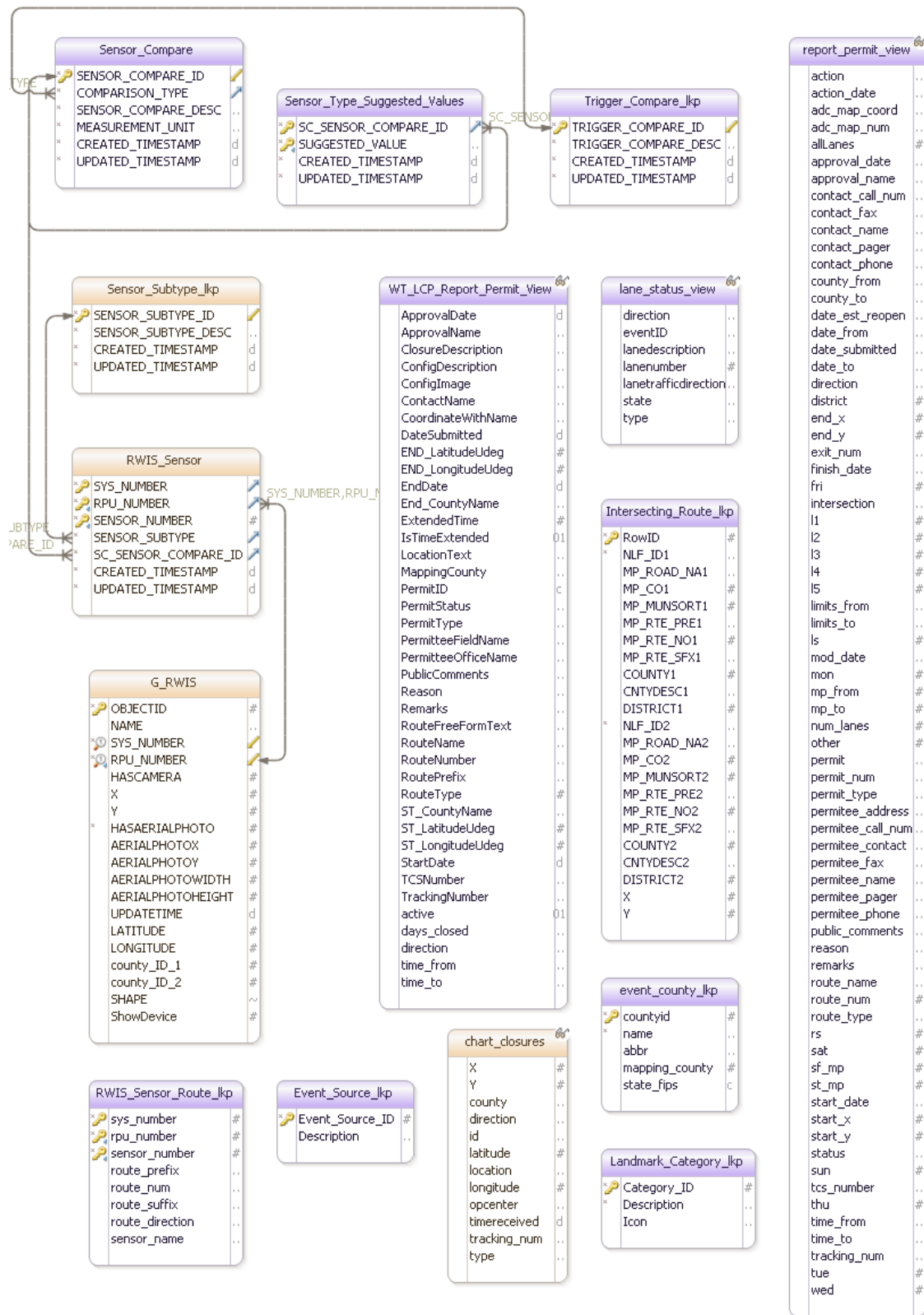


Figure B-8. CHARTWeb ERD Page 1

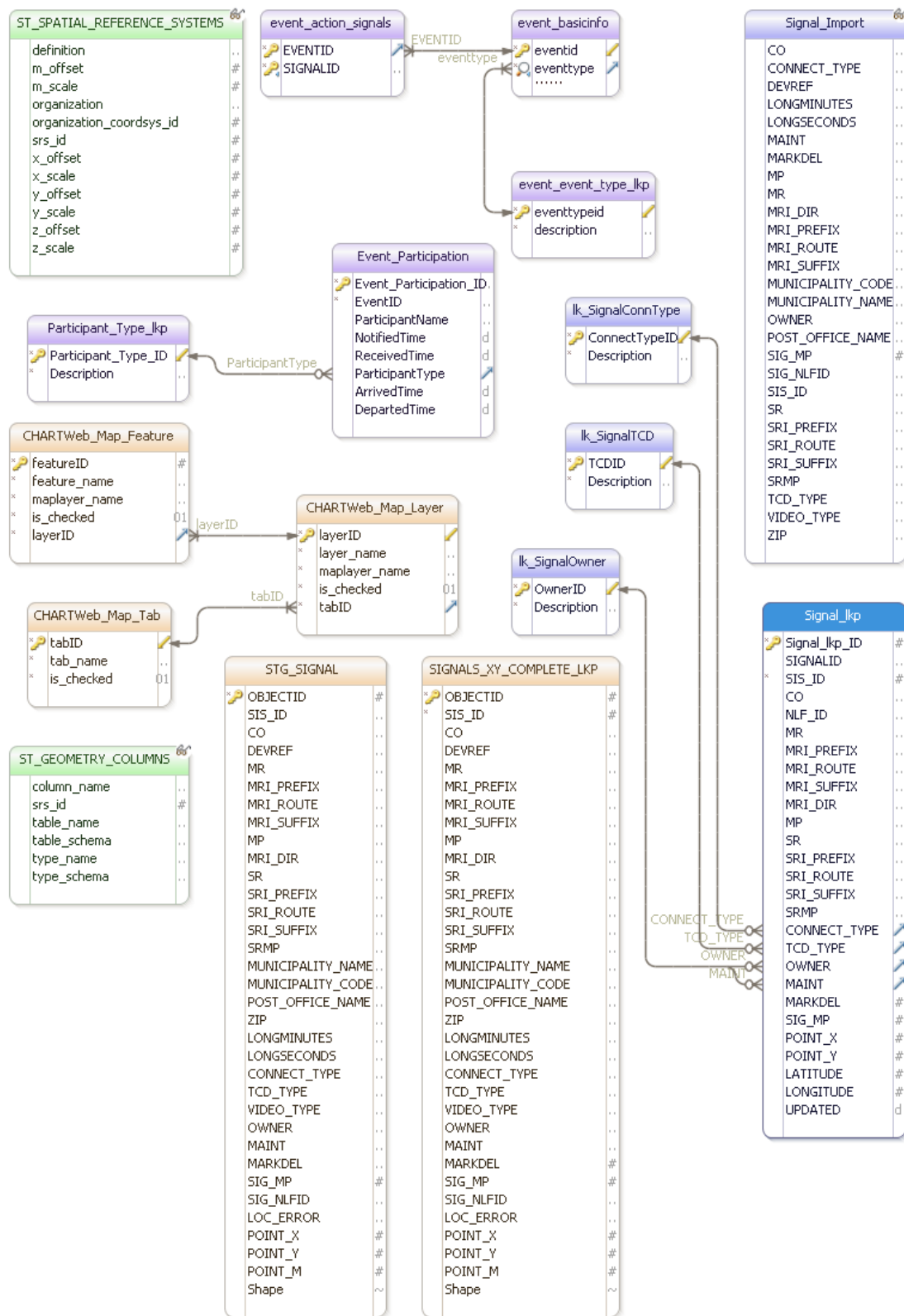


Figure B-9. CHARTWeb ERD Page 2

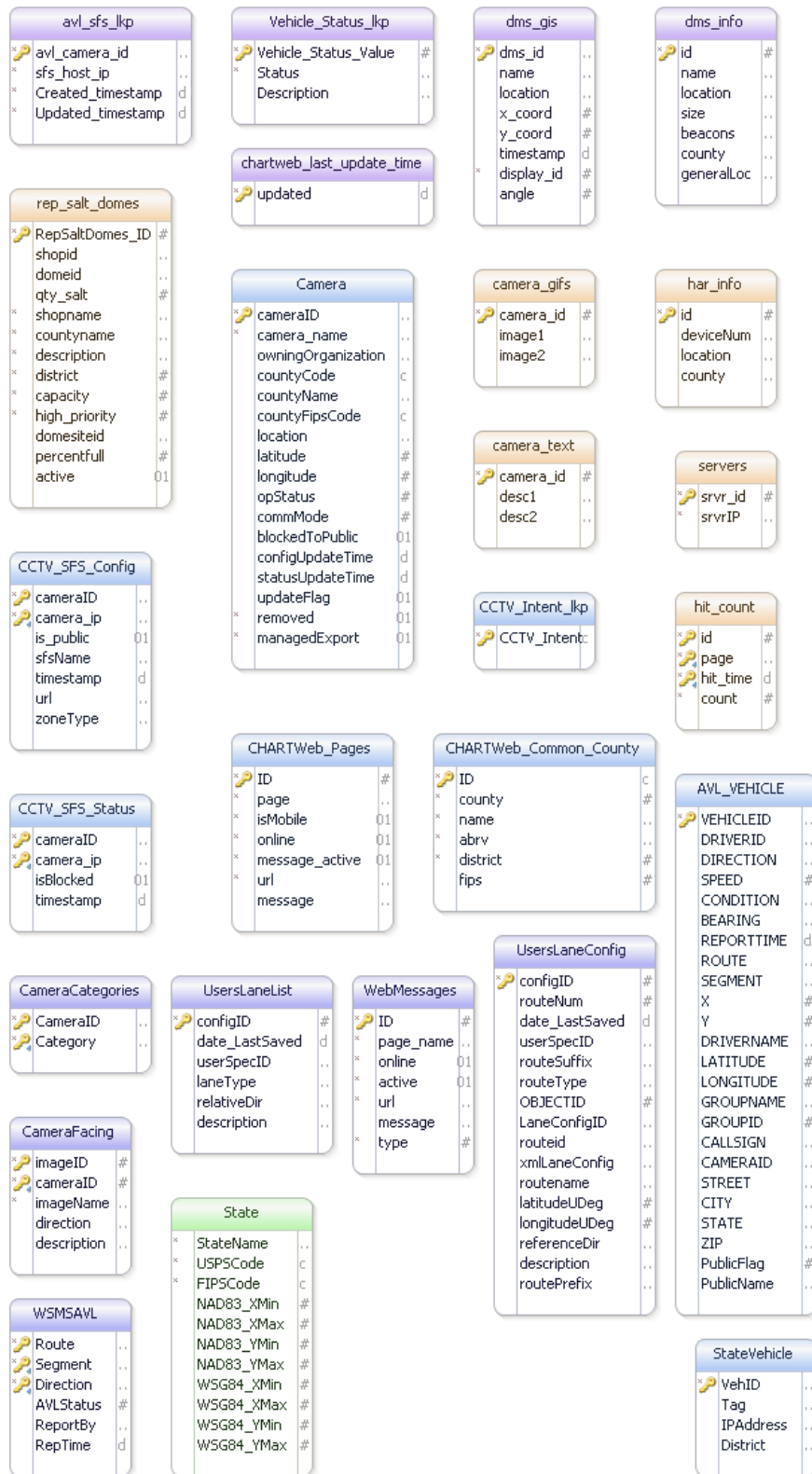


Figure B-11. CHARTWeb ERD Page 4

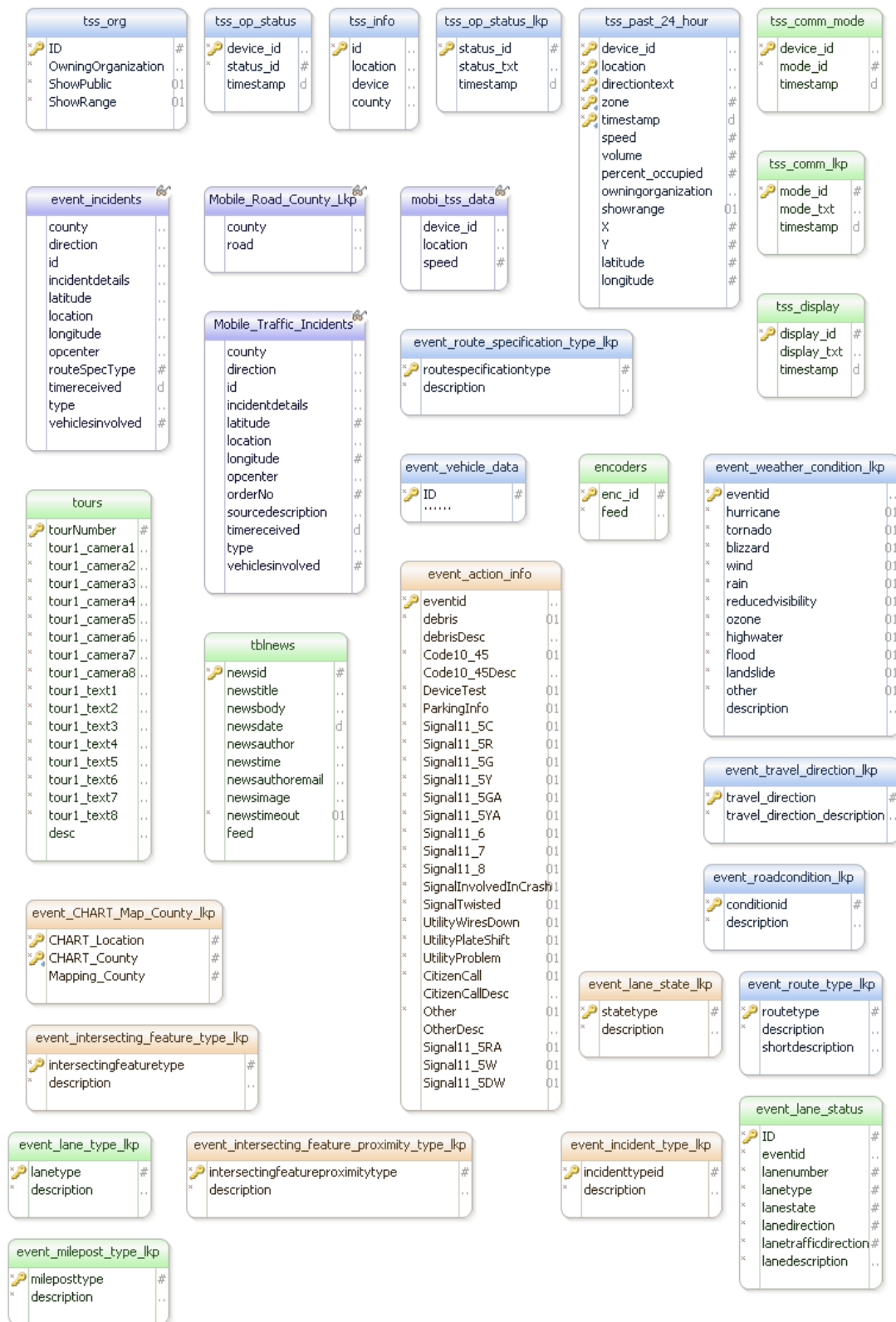


Figure B-12. CHARTWeb ERD Page 5

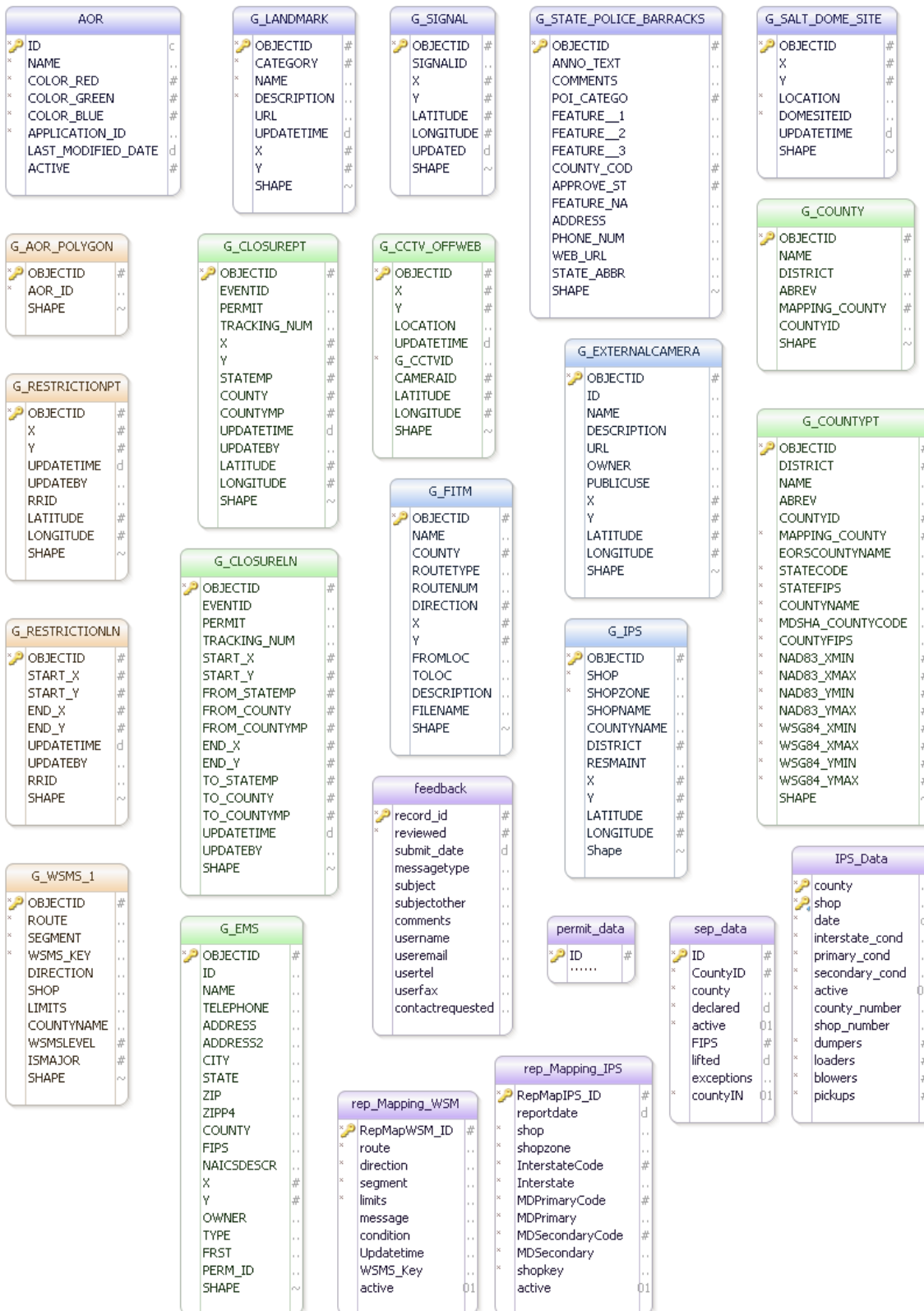


Figure B-13. CHARTWeb ERD Page 6

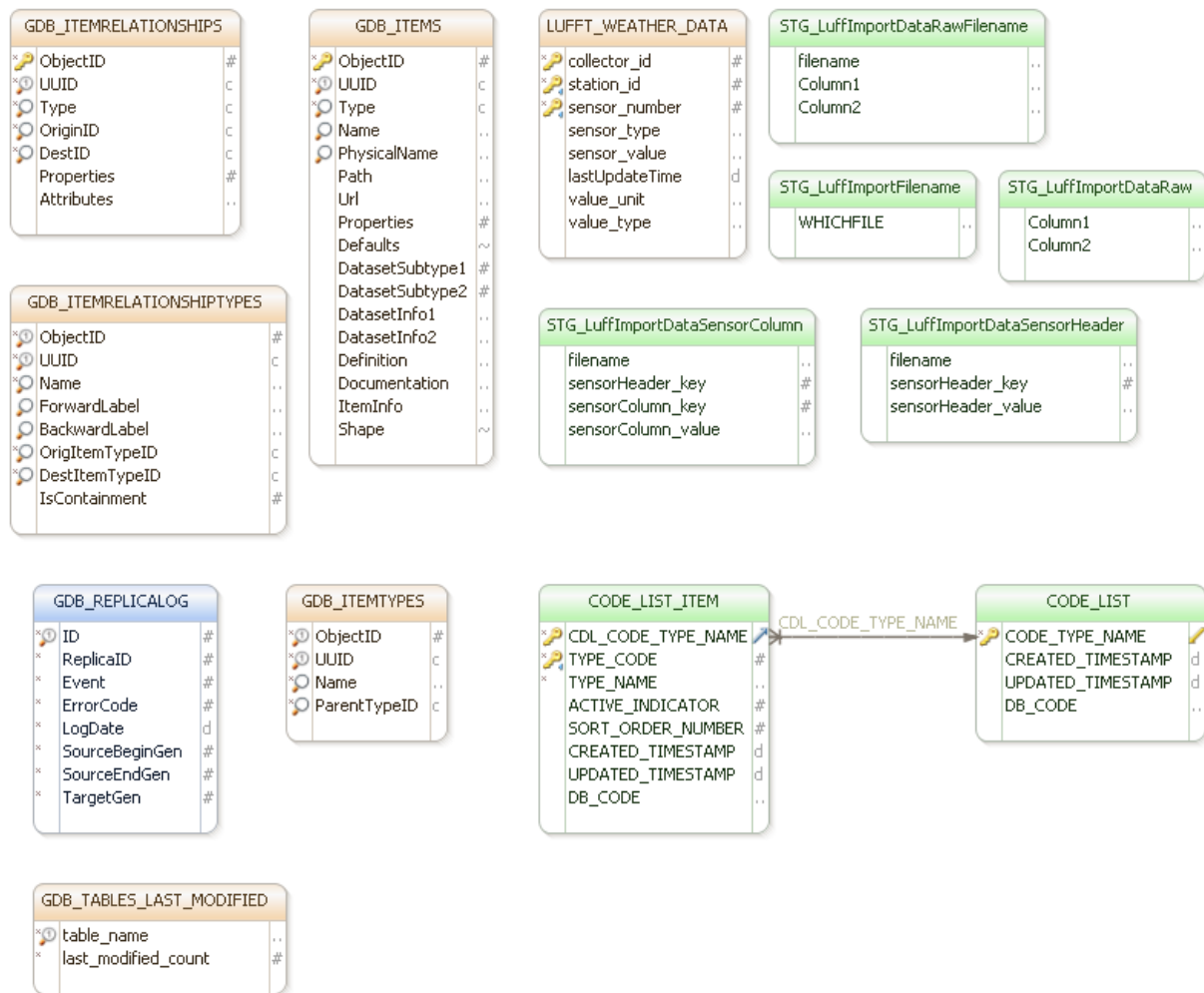


Figure B-14. CHARTWeb ERD Page 7

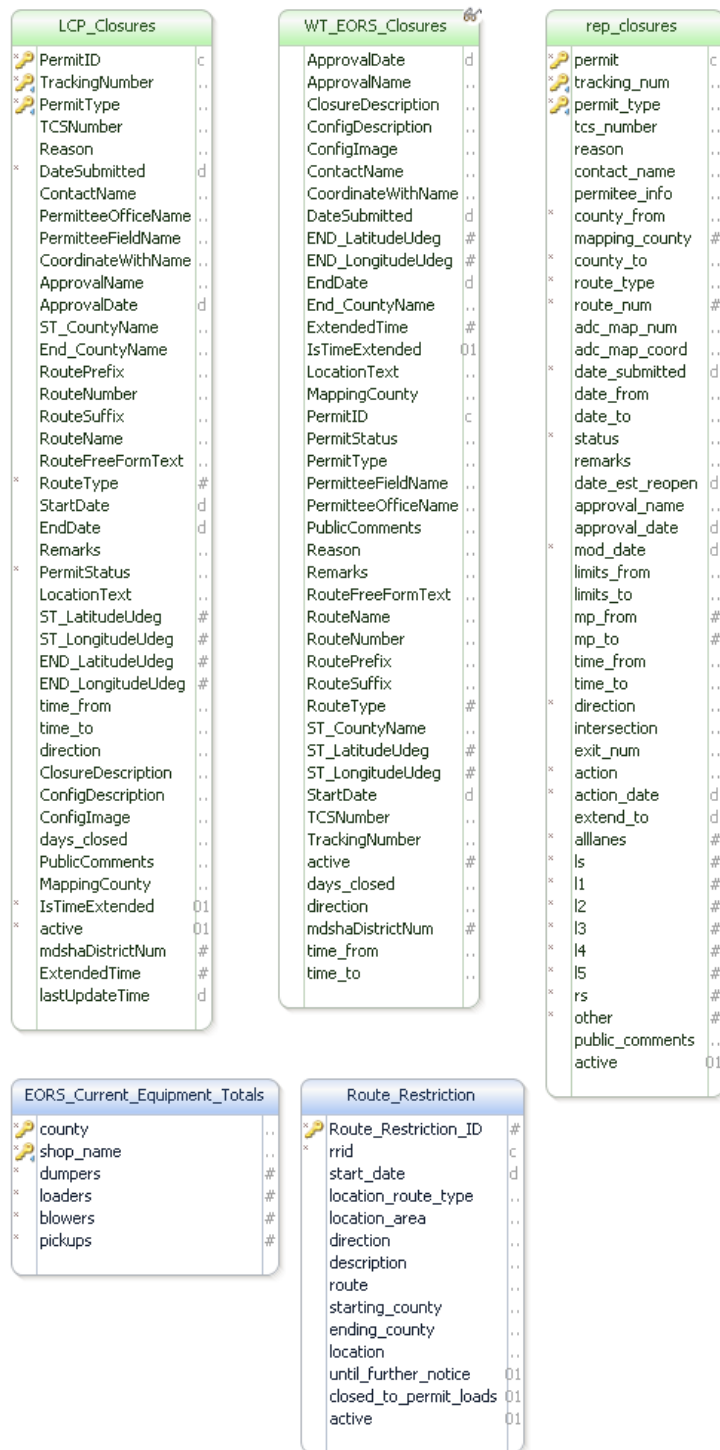


Figure B-15. CHARTWeb ERD Page 8

planned_closures		active_closures	
X	#	X	#
Y	#	Y	#
action	..	action	..
action_date	..	action_date	..
adc_map_coord	..	adc_map_coord	..
adc_map_num	..	adc_map_num	..
allLanes	#	allLanes	#
approval_date	..	approval_date	..
approval_name	..	approval_name	..
contact_call_num	..	contact_call_num	..
contact_fax	..	contact_fax	..
contact_name	..	contact_name	..
contact_pager	..	contact_pager	..
contact_phone	..	contact_phone	..
county_from	..	county_from	..
county_to	..	county_to	..
date_est_reopen	..	date_est_reopen	..
date_from	..	date_from	..
date_submitted	..	date_submitted	..
date_to	..	date_to	..
direction	..	direction	..
district	#	district	#
end_x	#	end_x	#
end_y	#	end_y	#
exit_num	..	exit_num	..
finish_date	..	finish_date	..
fri	#	fri	#
intersection	..	intersection	..
l1	#	l1	#
l2	#	l2	#
l3	#	l3	#
l4	#	l4	#
l5	#	l5	#
latitude	#	latitude	#
limits_from	..	limits_from	..
limits_to	..	limits_to	..
longitude	#	longitude	#
ls	#	ls	#
mod_date	..	mod_date	..
mon	#	mon	#
mp_from	#	mp_from	#
mp_to	#	mp_to	#
num_lanes	#	num_lanes	#
other	#	other	#
permit	..	permit	..
permit_num	..	permit_num	..
permit_type	..	permit_type	..
permittee_address	..	permittee_address	..
permittee_call_num	..	permittee_call_num	..
permittee_contact	..	permittee_contact	..
permittee_fax	..	permittee_fax	..
permittee_name	..	permittee_name	..
permittee_pager	..	permittee_pager	..
permittee_phone	..	permittee_phone	..
public_comments	..	public_comments	..
reason	..	reason	..
remarks	..	remarks	..
route_name	..	route_name	..
route_num	#	route_num	#
route_type	..	route_type	..
rs	#	rs	#
sat	#	sat	#
sf_mp	#	sf_mp	#
st_mp	#	st_mp	#
start_date	..	start_date	..
start_x	#	start_x	#
start_y	#	start_y	#
status	..	status	..
sun	#	sun	#
tcs_number	..	tcs_number	..
thu	#	thu	#
time_from	..	time_from	..
time_to	..	time_to	..
tracking_num	..	tracking_num	..
tue	#	tue	#
wed	#	wed	#

Figure B-16. CHARTWeb ERD Page 9

C RELEASE HISTORY

CHART systems have been evolving over a long period of time. Mapping has been deployed in multiple releases over several years. Hardware resources have been deployed in a phased manner to support each system release. A summary description of the system capabilities for each of the CHART Mapping releases is presented in the following sections. Note – history of releases 1 and 2 are missing.

C.1 CHART Mapping Release 3

Release 3 of Mapping was a COTS upgrade that upgraded the Mapping technology to use ESRI ArcGIS Server 9.3, Map Objects, and the ESRI Javascript API. This was deployed in the spring of 2009 on the existing Mapping servers. There was no additional Mapping functionality for this release, just a technology upgrade. The high level architecture/data flow is depicted in Figure D-1.

Table C-1. Mapping Release 3 Functions

CI	Subsystem	Function
COTS	ESRI ArcServer 9.3	Map Server
	ESRI Javascript API 1.6	ESRI API
	Microsoft Visual Studio 2005	Visual studio development/runtime version
	.NET framework 2.0	.NET version
Database Instance	Operational DB (CHARTWeb)	Microsoft SQLServer 2005

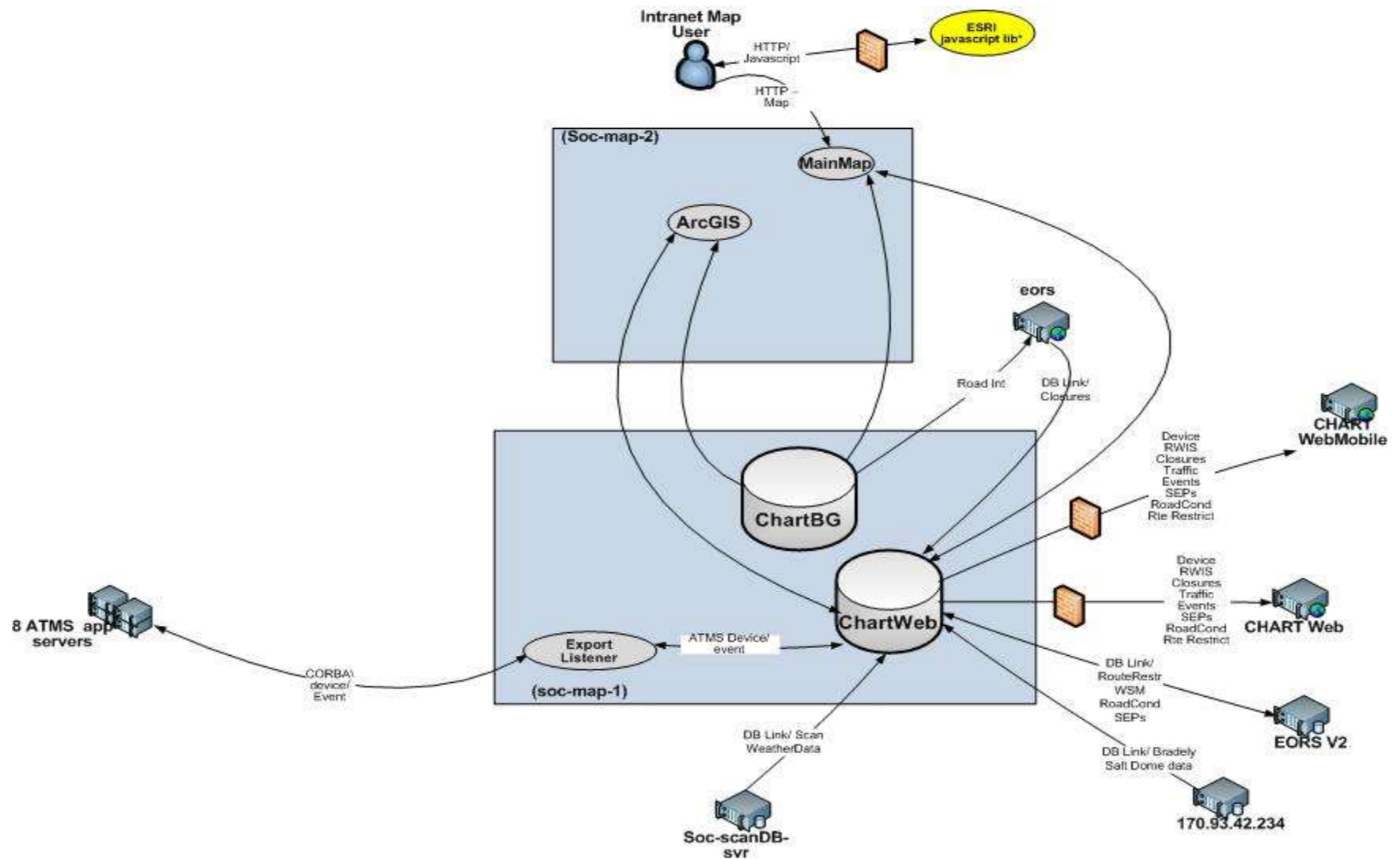


Figure C-1. CHART Mapping Release 3 High Level Architecture/Data Flow

C.2 CHART Mapping Release 4

Release 4 of Mapping is a significant upgrade to provide support for CHART ATMS Mapping integration (Release 5 of ATMS). Mapping Release 4 provides map background tiles, and exit/mileposts tiles for display in ATMS. In addition, the mechanism for sending ATMS data to the CHARTWeb database for display by Intranet Map and CHARTWeb was changed. The old ExportListener, which has a CORBA front end to communicate with ATMS was re-written in favor of the ExportClient which has an HTTP/XML interface to ATMS. In addition, the data the ATMS exports now contains location information for Traffic events and ATMS devices, including lat/lon. Mapping Release 4 provided upgrades to display these ATMS events and devices on the Intranet Map automatically, without the need to locate these points using the Device Editor or Event mapping interface. Note that for ATMS Release 5/Mapping Release 4, cameras and TSSs are still located manually using the Mapping Device Editor.

In addition Mapping Release 4 contains enhancement to include satellite imagery (from the Md iMap server), new points of interest (POIs) including Maryland state police and 911 center locations.

Table C-2. Mapping Release 4 Functions

CI	Subsystem	Function
Internal Map REST Services	CHARTBG_Cache	Map tile cache for ATMS
	CHART_Exits_Mileposts_Cache	Exit/milepost map tile cache for ATMS
Database Instance	Operational DB (CHARTWeb)	ATMS Event, Device table updates
Web Services	GISService	Return Exits and mileposts given a county and primary route

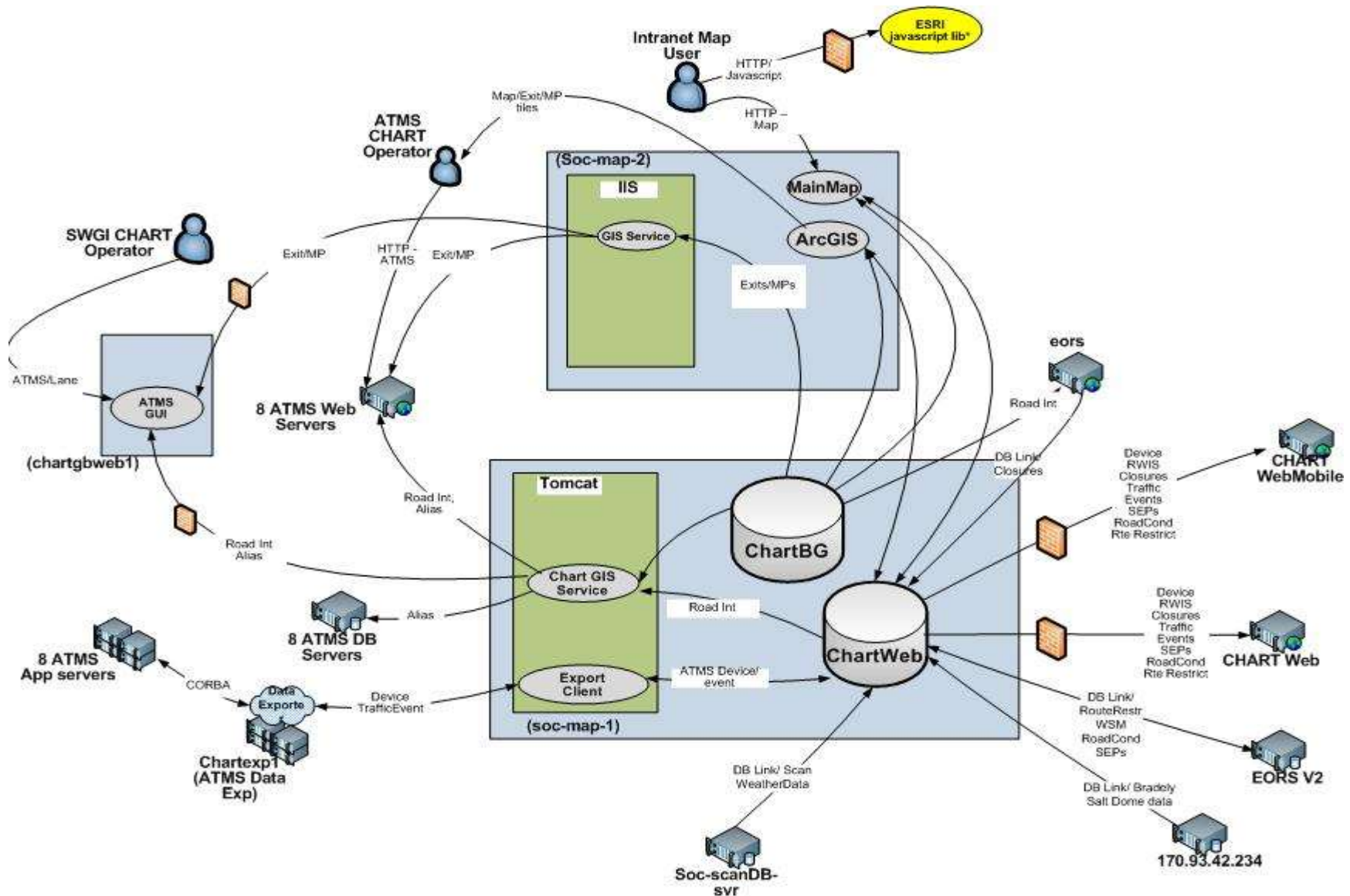


Figure C-2. CHART Mapping Release 4 High Level Architecture/Data Flow

C.3 CHART Mapping Release 5

Release 5 of Mapping is another significant upgrade to provide support for CHART ATMS Mapping integration (Release 6 of ATMS). Mapping Release 5 provides a new Lane Configuration Service. Clients (in this case ATMS) may request lane configuration information at a specified location or send a user defined lane configuration at a location for retrieval by subsequent requests. In addition both ATMS Release 6 and Mapping Release 5 support camera locations and automatic mapping of cameras, similar to other ATMS devices. Finally, there are mechanisms in place to support display of detailed speed information for external TSSs (e.g., Navteq owned TSSs) on the Intranet Map based on Map user privilege. This is implemented in a new ATMS Release 6 UserManager service that is called by users of the Mapping R5 intranet Map.

Finally, Mapping R5 encompasses enhancements to the original Mapping Release 4 for public and non-public external REST services, and the addition of satellite and hybrid imagery on the intranet Map. The external REST services are hosted on the GB-DC DMZ. Consumers (initially MEMA Osprey) may consume this data for display on their own maps and for consumption of the underlying data. The non-public interface serves a large portion of the map data available to the Intranet map while the public interface contains a reduced data set with fewer details.

Table C-3. Mapping Release 5 Functions

CI	Subsystem	Function
Internal Map REST Services	CHARTWEB_TSS	TSS display on Intranet Map
External Map REST Services	iMap	Public external REST service
	iMap_Non_Public	Non-public external REST service (controlled by login)
Database Instance	Operational DB (CHARTWeb)	ATMS Camera, TSS table updates
WebServices	LaneConfigService	Add Lane Configuration service

c.4 CHART Mapping Release 6

Release 6 of Mapping supports automatic display of TSSs on the Intranet Map based on the TSS bearing now exported by ATMS Release 7. With this, the Mapping device editor is no longer needed to orient the TSS arrows for display on the intranet Map. This means that the device editor can be retired.

Table C-4. Mapping Release 6 Functions

CI	Subsystem	Function
Internal Map REST Services	CHARTWEB_TSS	Automatic display of TSS, including correct bearing
Database Instance	Operational DB (CHARTWeb)	TSS related table updates

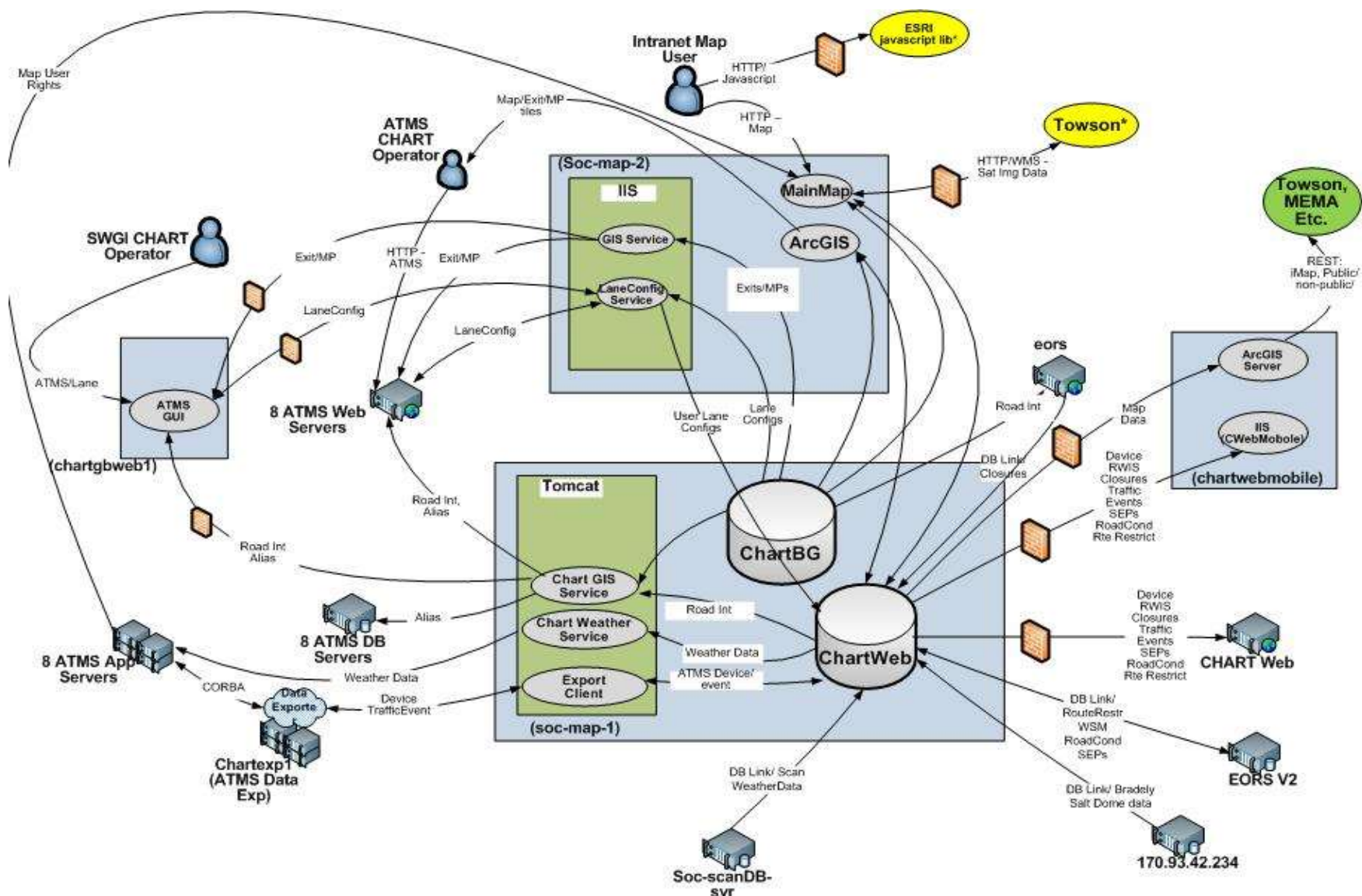


Figure C-4. CHART Mapping Release 6 High Level Architecture/Data Flow

C.5 CHART Mapping Release 7

Release 7 of Mapping is a significant enhancement to display AVL equipped vehicles on the Intranet Map, including the capability to view video associated with those vehicles (where available). A new Mapping Service, AVL Client, connects to and consumes data from a CHART developed AVL server – which consumes and supplies AVL data from/to Telenav.

Since Release 6 of Mapping, Map services have been deployed on the State Wide Government Intranet (SWG I) and several POIs have been added: Toll booths, Light Rail, subway/metro, and MARC stations.

Table C-5. Mapping Release 7 Functions

CI	Subsystem	Function
AVL Client	CHARTAVL	Display of AVL equipped vehicles on the Intranet map including video where available
Database Instance	Operational DB (CHARTWeb)	AVL related table updates

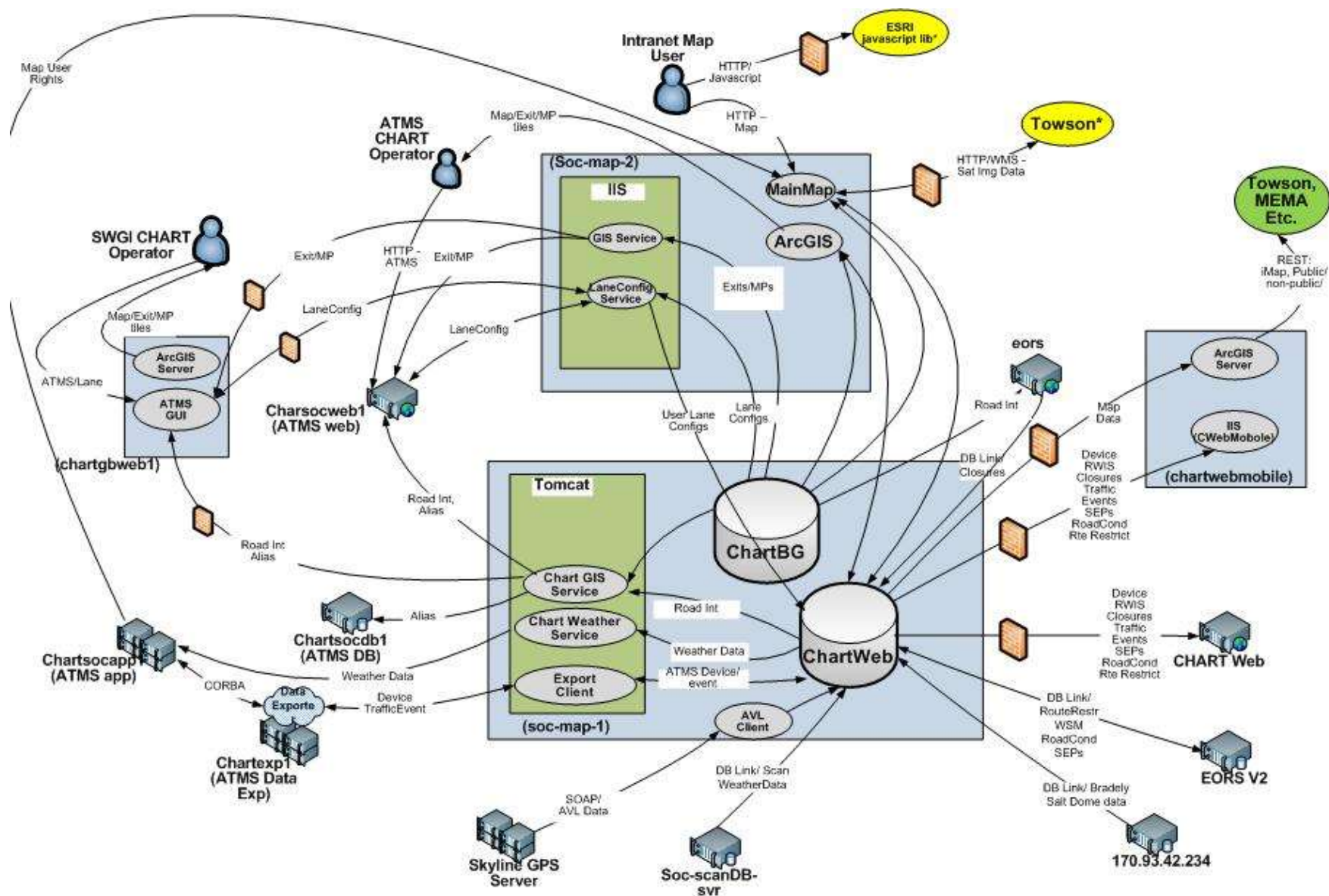


Figure C-5. CHART Mapping Release 7 High Level Architecture/Data Flow

C.6 CHART Mapping Release 8

Release 8 of Mapping contains enhancements to support the ATMS Release 9 Decision Support capabilities. New interfaces were created in the GISService to support requests for proximity information for devices given an event location. That information is used by ATMS to present operators with the suggested devices for a traffic event.

Mapping Release 8 also encompasses earlier enhancements since Mapping Release 7. This includes the ability to display an overlay of INRIX speed data on the Intranet Map. It also includes the capability to display RWIS data from the new Lufft system on the Intranet Map.

Table D-6. Mapping Release 8 Functions

CI	Subsystem	Function
Web Services	GISService	Support Decision Support queries for proximity information
Database Instance	Operational DB (CHARTWeb)	RWIS related table updates

C.7 CHART Mapping Release 9

Release 9 of Mapping provides a new web service to read/write Area of Responsibility (AOR) polygons for use in ATMS Release 10.

Mapping Release 9 also encompasses earlier enhancements since Mapping Release 8. This includes an external AVL REST feed and a KML feed for use by MDTA to display CHART Mapping data on a Google map.

Table C-7. Mapping Release 9 Functions

CI	Subsystem	Function
External REST Services	CHARTAVL_REST	AVL REST for external (non-public) users
	CHART_Non_Public_KMZ	KML feed for MDTA
Web Services	MapGISService	AORs
Database Instance	Operational DB (CHARTWeb)	New tables to support AORs

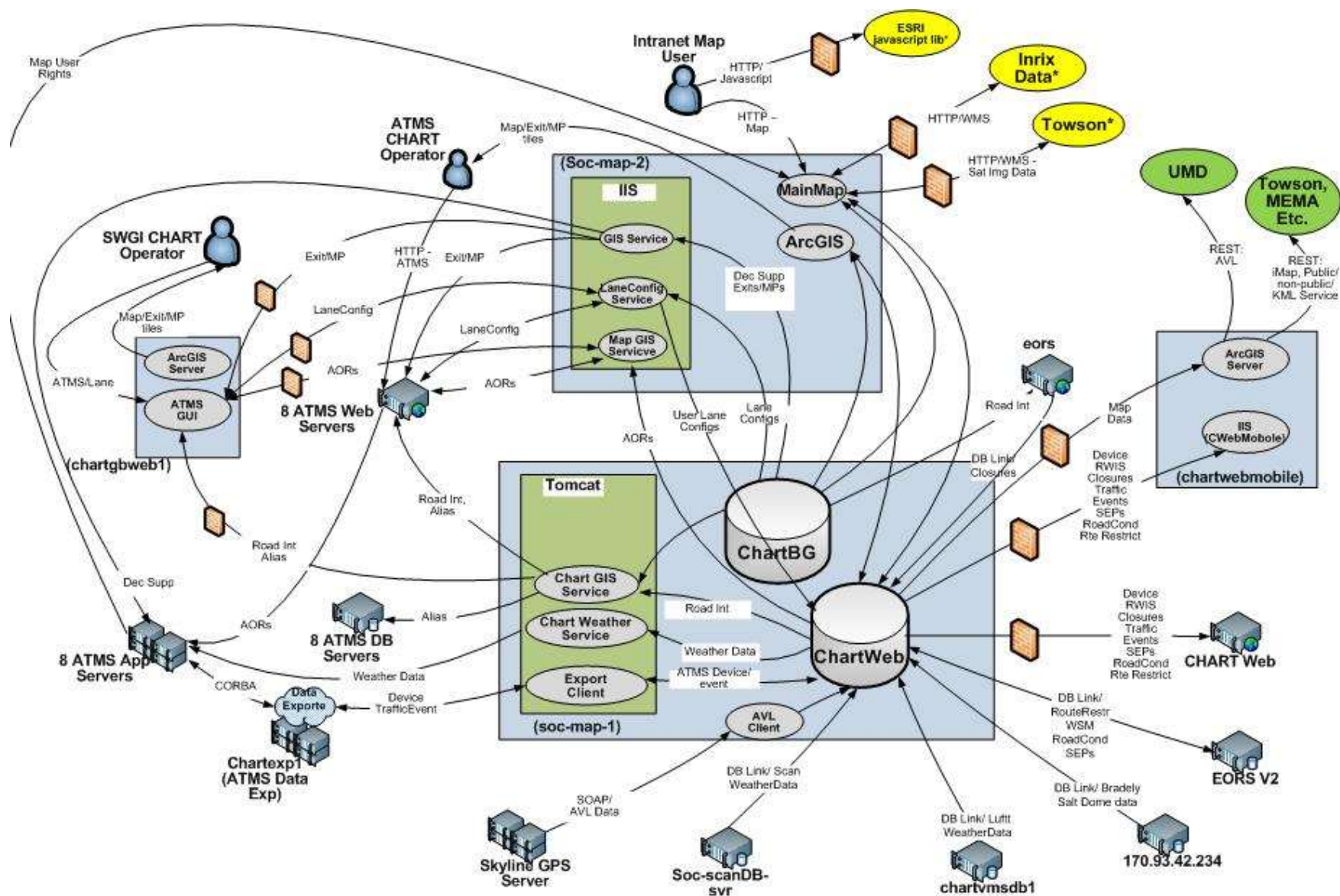


Figure C-7. CHART Mapping Release 9 High Level Architecture/Data Flow

C.8 CHART Mapping Release 10

Release 10 of Mapping provides some enhancements to the Decision Support capabilities of the GIS Service to accommodate special situations for Highway Advisory Radios (HARs). Also, a database link to the source server for Signal information to support the ATMS Signal Service and to provide updated signal location information to the Intranet Map was created.

Also, depicted in the architecture diagram, though not directly related to Mapping, is that the ATMS is consolidated into a single node.

Table C-8 Mapping Release 10 Functions

CI	Subsystem	Function
Web Services	GISService	Decision support enhancements
Database Instance	Operational DB (CHARTWeb)	New link to Signal Book database

C.9 CHART Mapping Release 11

Release 11 of Mapping is a major COTS upgrade to Mapping that necessitated re-writing much of the code. The prime objective of this release is to upgrade the ArcGIS Server from version 9.3 to version 10.1 in all parts of the Mapping applications; Intranet Map, the AVL Client, and the GIS web services. To support the ArcGIS Server upgrade, the base technology platform for the application is upgraded, including the following:

- Windows Server from 2003 to 2008R2.
- MS SQL Server from 2005 to 2008R2
- .NET Framework from version 2.0 to version 4.5
- ESRI Javascript API from version 1.6 to version 3.9.

The ArcGIS Server upgrade includes major reworks to the existing code base to remove the outdated MapObjects API and replace with the newer ArcGIS Server 10.1 API. This change affects all key components of the mapping applications and web services. Additionally the AVL client will be reworked to address known performance issues

This Mapping release also introduced a warm backup Mapping site and SHA HQ, with mirrored CHARTWeb/CHARTBG databases.

Table C-9 Mapping Release 11 Functions

CI	Subsystem	Function
COTS	ESRI ArcServer 10.1	Upgrade from 9.3 to 10.1
	ESRI Web Adapter 10.1	New in Mapping R11. Front end for external REST services.
	ESRI Javascript API 3.9	Upgrade from 1.6 to 3.9
	Microsoft Visual Studio 10	Upgrade from 2005 to 2010
	NET framework 4.5	Upgrade from 2.0 to 4.5
	Microsoft Windows	Upgrade from 2003 to 2008
	Microsoft SQL Server	Upgrade from 2005 to 2008
Database Instance	Operational DB (CHARTWeb)	DBs upgraded from SQLServer 2005 to 2008

C.10 CHART Mapping Release 12

Release 12 of Mapping provides enhancements for ATMS R12 Decision Support by adding the ESRI Network Analyst extension and editing the road data to build a network suitable for routing. These enhancements allow ATMS to get driving directions between an incident and a device to better determine which devices are relevant for a traffic event, including devices on a different route than the traffic event.

Mapping Release 12 also encompasses earlier enhancements in support of the Lane Closure Permits (LCP) system. LCP is a replacement for EORS legacy.

Table C-10 Mapping Release 12 Functions

CI	Subsystem	Function
COTS	ESRI Network Analyst Extension	Used for ATMS R12 Decision support enhancements
Database Instance	Operational DB (CHARTBG, CHARTWeb)	CHARTBG roads edited to create network of major roadways. CHARTWeb tables modified to support LCP.

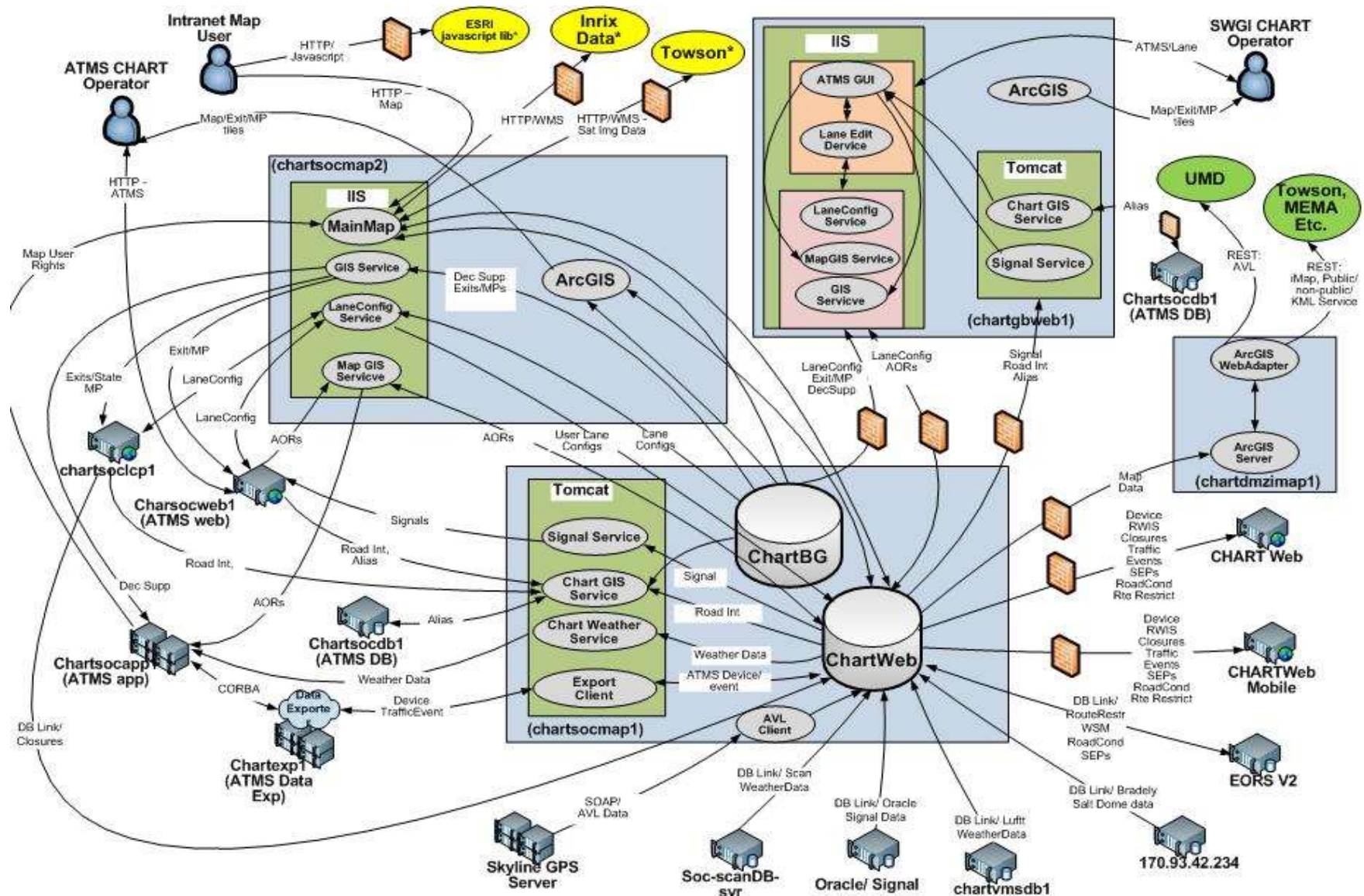


Figure C-10. CHART Mapping Release 12 High Level Architecture/Data Flow

C.11 CHART Mapping Release 14

Release 14 of Mapping provides enhancements for ATMS R13 by providing proximity information related to FITM plans. Release 14 of Mapping also provides enhancements to the GISService to return county milepoints in addition to state mileposts.

CI Name	Subsystems
Internal Map REST Services	CHARTWEB_JS2_QL CHARTWEB_JS2 CHART_Centerline_Routes CHART_Exits_Mileposts_Cache CHARTAVL CHARTBG_Cache CHARTBG_GG CHARTDevice_Editor CHARTWEB_JS2_FS CHARTWEB_TSS
External Map REST Services	iMap iMap_Non_Public CHART_Non_Public_KMZ CHART_Public_Mobile CHART_Public_PC CHARTAVL_REST
Web Services	GISService MapGISService
AVL Client	AVLClient
Database Instance	Operational DB
COTS	ESRI ArcServer 10.1 ESRI Network Analyst Extension ESRI Web Adapter 10.1 ESRI Javascript APPI 3.9 Microsoft Visual Studio 10 .NET framework 4.5 IBM Rational RequisitePro Microsoft SQL Server Microsoft SQL Server JDBC Driver Microsoft Windows Subversion Subversion browser TortoiseSVN

Table C-11 Mapping Release 14 Functions

CI	Subsystem	Function
Web Services	GISService	Enhancements for FITM proximity and county milepoints

C.12 CHART Mapping Release 15

Release 15 of Mapping provides LCP Data Exporter support and per district Permit layers on the Intranet Map.

CI Name	Subsystems
IntranetMap	IntranetMap
Internal Map REST Services	CHARTWEB_JS2_QL CHARTWEB_JS2 CHART_Centerline_Routes CHART_Exits_Mileposts_Cache CHARTAVL CHARTBG_Cache CHARTBG_GG CHARTDevice_Editor CHARTWEB_JS2_FS CHARTWEB_TSS
External Map REST Services	iMap iMap_Non_Public CHART_Non_Public_KMZ CHART_Public_Mobile CHART_Public_PC CHARTAVL_REST
Web Services	GISService MapGISService
AVL Client	AVLClient
Database Instance	Operational DB
COTS	ESRI ArcServer 10.1 ESRI Network Analyst Extension ESRI Web Adapter 10.1 ESRI Javascript API 3.9 Microsoft Visual Studio 10 .NET framework 4.5 IBM Rational RequisitePro Microsoft SQL Server Microsoft SQL Server JDBC Driver Microsoft Windows Subversion Subversion browser TortoiseSVN

Table C-12 Mapping Release 15 Functions

CI	Subsystem	Function
IntranetMap	IntranetMap	Per district LCP closures on the Intranet map

C.13 CHART Mapping Release 16

Release 16 of Mapping provides a base Map upgrade with the latest available SHA data. This includes CHART centerline conflation, establishing an ESRI Network Analyst dataset, geometry and network attribution modifications, network improvements, documentation, and regeneration of the BG Cache Tiles and Map Service.

CI Name	Subsystems
IntranetMap	IntranetMap
Internal Map REST Services	CHARTWEB_JS2_QL CHARTWEB_JS2 CHART_Centerline_Routes CHART_Exits_Mileposts_Cache CHARTAVL CHARTBG_Cache CHARTBG_GG CHARTDevice_Editor CHARTWEB_JS2_FS CHARTWEB_TSS
External Map REST Services	iMap iMap_Non_Public CHART_Non_Public_KMZ CHART_Public_Mobile CHART_Public_PC CHARTAVL_REST
Web Services	GISService MapGISService
AVL Client	AVLClient
Database Instance	Operational DB
COTS	ESRI ArcServer 10.1 ESRI Network Analyst Extension ESRI Web Adapter 10.1 ESRI Javascript API 3.9 Microsoft Visual Studio 10 .NET framework 4.5 IBM Rational RequisitePro Microsoft SQL Server Microsoft SQL Server JDBC Driver Microsoft Windows

CI Name	Subsystems
	Subversion Subversion browser TortoiseSVN

Table C-13 Mapping Release 16 Functions

CI	Subsystem	Function
Internal Map REST Services	CHARTWEB_JS2 CHART_Centerline_Routes CHART_Exits_Mileposts_Cache CHARTBG_Cache CHARTBG_GG	Updates for SHA data Upgrade

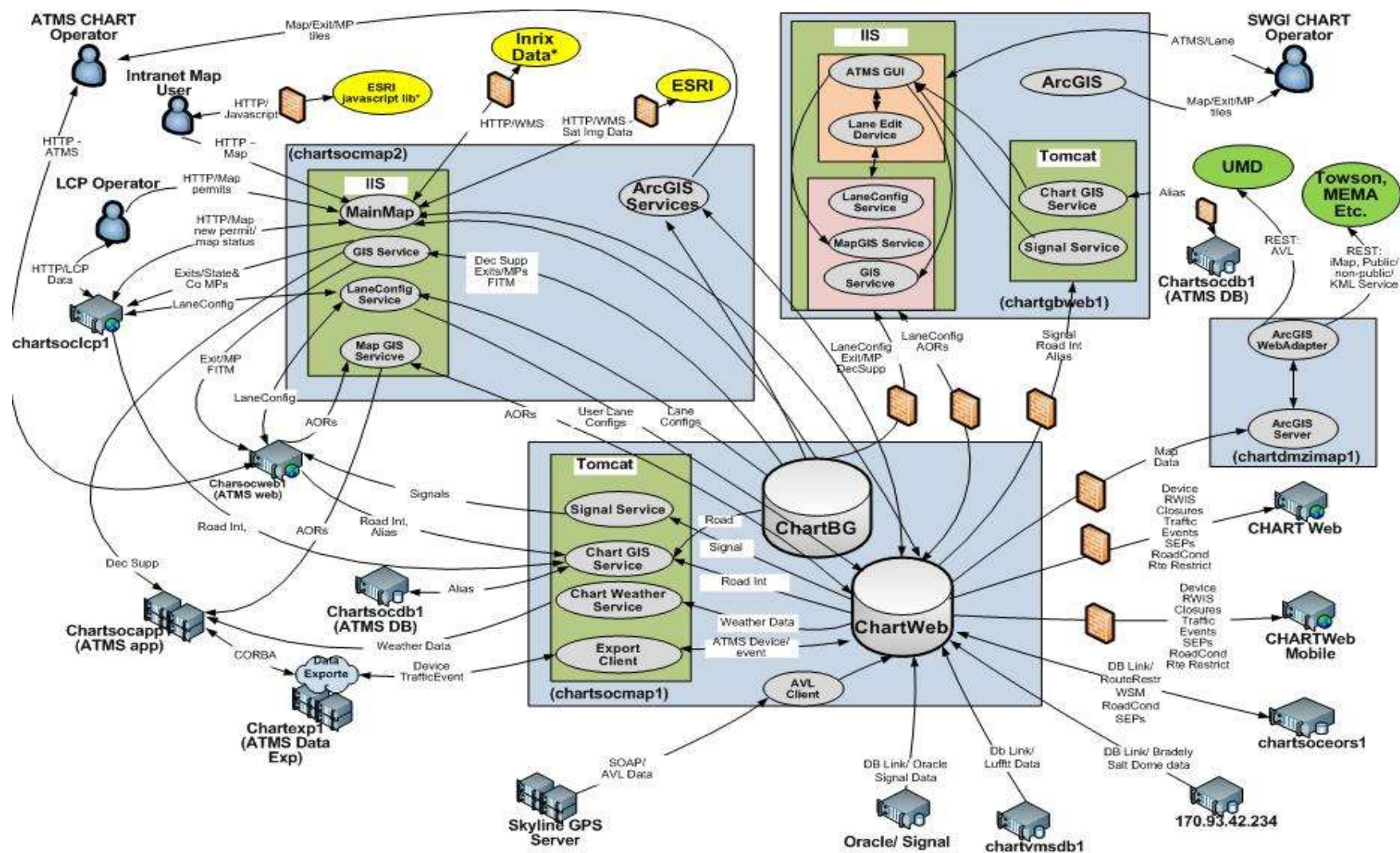


Figure C-13. CHART Mapping Release 16 High Level Architecture/Data Flow

C.14 CHART Mapping Release 17

Release 17 of Mapping provide re-architecture of weather data interfaces with the Lufft system. There was also some re-architecture of ATMS camera related interfaces that required adjustments in Mapping. Note that there is a CHARTWeb Public database that was implemented in an R16 patch. Significant work items in later Release 17 patches include incorporating an updated DSED milepoint data set (17.2), and updates to AVL layers (17.3).

CI Name	Subsystems
IntranetMap	IntranetMap
Internal Map REST Services	CHARTWEB_JS2_QL CHARTWEB_JS2 CHART_Centerline_Routes CHART_Exits_Mileposts_Cache CHARTAVL CHARTBG_Cache CHARTBG_GG CHARTDevice_Editor CHARTWEB_JS2_FS CHARTWEB_TSS
External Map REST Services	iMap iMap_Non_Public CHART_Non_Public_KMZ CHART_Public_Mobile CHART_Public_PC CHARTAVL_REST
Web Services	GISService MapGISService
AVL Client	AVLClient
Database Instance	CHARTWeb DB CHARTBG DB CHARTWeb Public DB
COTS	ESRI ArcServer 10.1 ESRI Network Analyst Extension ESRI Web Adapter 10.1 ESRI Javascript API 3.9 Microsoft Visual Studio 11 .NET framework 4.5 Microsoft SQL Server

CI Name	Subsystems
	Microsoft SQL Server JDBC Driver Microsoft Windows Subversion Subversion browser TortoiseSVN

Table C-14 Mapping Release 17 Functions

CI	Subsystem	Function
Intranet Map	Intranet Map	Updates for Camera Data
Internal Map REST Services	CHARTWEB_JS2 CHARTWEB_JS2_QL	Updates for Weather and Camera Data
External Map REST Services	iMap iMap_Non_Public CHART_Non_Public_KMZ CHART_Public_Mobile CHART_Public_PC CHARTAVL_REST	Updates for Weather and Camera Data
Web Services	GISService MapGISService	
Database Instance	CHARTWeb DB CHARTWeb Public DB	Updates for Weather and Camera Data

C.15 CHART Mapping Release 18

Release 18 of Mapping is a major COTS upgrade for ESRI ArcGIS solution for Mapping. Along with the ESRI upgrade there are several changes being made for a list of mapping PR's. The prime objective of this release is to upgrade the ArcGIS Server from version 10.1 to 10.5 in all parts of the Mapping applications; Intranet Map, the Map tile cache, the AVL Client, and the GIS web services. To support the ArcGIS Server upgrade, the base technology platform for the application is upgraded, including the following:

- Windows Server from 2008 to 2012
- MS SQL Server from 2008R2 to 2014
- .NET Framework from version 4.5 to version 4.6.2

The PR's included with this Release contain changes to various mapping components, such as signals, weather data, etc.

The ArcGIS Server upgrade does not include any changes to the existing code base, however there were few database changes to address the ESRI bug for Network Analyst where it cannot handle the datetime columns. Since this change affects all key components of the mapping applications and web services, substantial emphasis will be placed on a complete system regression test.

CI Name	Subsystems
IntranetMap	IntranetMap
Internal Map REST Services	CHARTWEB_JS2_QL CHARTWEB_JS2 CHART_Centerline_Routes CHART_Exits_Mileposts_Cache CHARTAVL CHARTBG_Cache CHARTBG_GG CHARTDevice_Editor CHARTWEB_JS2_FS CHARTWEB_TSS
External Map REST Services	iMap iMap_Non_Public CHART_Non_Public_KMZ CHART_Public_Mobile CHART_Public_PC CHARTAVL_REST

CI Name	Subsystems
Web Services	GISService MapGISService
AVL Client	AVLClient
Database Instance	CHARTWeb DB CHARTBG DB CHARTWeb Public DB
COTS	ESRI ArcServer 10.5 ESRI Network Analyst Extension ESRI Web Adapter 10.5 .NET framework 4.6.2 Microsoft SQL Server 2014 SQL Server Native Client 2014

Table C-14 Mapping Release 18 Functions

CI	Subsystem	Function
Intranet Map	Intranet Map	Updates for PR's that include changes for MDTA layer, weather, signals, etc.
Internal Map REST Services	CHARTWEB_JS2 CHARTWEB_JS2_QL	Updates for MDTA TSS layer
External Map REST Services	iMap iMap_Non_Public CHART_Non_Public_KMZ CHART_Public_Mobile CHART_Public_PC CHARTAVL_REST	Updates for Weather and TSS Data
Web Services	GISService MapGISService	None
Database Instance	CHARTWeb DB CHARTWeb Public DB	Updates for Weather and Signals Data

